INSTITUTION

OF

MECHANICAL ENGINEERS.

PROCEEDINGS.

1860.

PUBLISHED BY THE INSTITUTION,
81 NEWHALL STREET, BIRMINGHAM.

1860.

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1860.

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LIST OF MEMBERS,

WITH YEAR OF ELECTION.

1860.

LIFE MEMBERS.

1852. Brogden, Henry, Sale, near Manchester.
1858. Fletcher, Henry Allason, Lowca Engine Works, Whitehaven.
1857. Haughton, S. Wilfred, Locomotive Superintendent, Dublin Wicklow and Wexford Railway, Dublin.
1854. Lloyd, George Braithwaite, Messrs. Lloyds, High Street, Birmingham.
1853. Maudslay, Henry, 4 Cheltenham Place, Lambeth, London, S.
1848. Penn, John, The Cedars, Lee, Kent, S.E.

MEMBERS.

1859. Adams, William, Locomotive Superintendent, North London Railway, Bow, London, E.
1848. Adams, William Alexander, Midland Works, Birmingham.
1859. Adamson, Daniel, Newton Moor Iron Works, Hyde, near Manchester.
1851. Addison, John, 6 Delahay Street, Westminster, S.W.
1853. Adkins, Francis, Heath Lead Works, near Birmingham.
1858. Albaret, Auguste, Engine Works, Liancourt, Oise, France.
1847. Allan, Alexander, Locomotive Superintendent, Scottish Central Railway, Perth.
1856. Allen, Edward Ellis, 2 Brunswick Place, Brompton, London, S.W.
1856. Allen, James, Cambridge Street Works, Manchester.
1859. Alton, George, Midland Railway Works, Derby.
1856. Anderson, John, Assistant Superintendent, Royal Gun Factories, Royal Arsenal, Woolwich, S.E.
1856. Anderson, William, Messrs. Courtney Stephens and Co., Blackall Place Iron Works, Dublin.
1858. Appleby, Charles Edward, Mining Engineer, 39 Mornington Road, Regent's Park, London, N.W.
1859. Armitage, William James, Farnley Iron Works, Leeds.
1857. Armstrong, Joseph, Great Western Railway, Locomotive Department, Wolverhampton.

1858. Armstrong, Sir William George, Elswick, Newcastle-on-Tyne.
1857. Ashbury, James Lloyd, Openshaw Works, near Manchester.
1848. Ashbury, John, Openshaw Works, near Manchester.
1858. Atkinson, Charles, Fitzalan Steel Works, Sheffield.

1848. Bagnall, William, Gold's Hill Iron Works, Westbromwich.
1860. Bailey, Samuel, Mining Engineer, The Pleck, near Walsall.
1848. Baker, William, London and North Western Railway, Euston Station, London, N.W.
1860. Barclay, John, Bowling Iron Works, near Bradford, Yorkshire.
1860. Barker, Paul, Old Park Iron Works, Wednesbury.
1847. Barwell, William Harrison, Eagle Foundry, Northampton.
1859. Bastow, Samuel, Cliff House Iron Works, West Hartlepool.
1860. Batho, William Fothergill, Bordesley Works, Birmingham.
1859. Beacock, Robert, Victoria Foundry, Leeds.
1860. Beale, William Phipson, Parkgate Iron Works, Rotherham.
1848. Beattie, Joseph, Locomotive Superintendent, London and South Western Railway, Nine Elms, London, S.
1859. Beck, Edward, Jun., Messrs. Neild and Co., Dallam Iron Works, Warrington.
1860. Beck, Richard, Messrs. Smith Beck & Beck, 6 Coleman Street, London, E.C.
1858. Bell, Isaac Lowthian, Clarence Felling and Wylam Iron Works, Newcastle-on-Tyne.
1857. Bellhouse, Edward Taylor, Eagle Foundry, Hunt Street, Oxford Street, Manchester.
1854. Bennett, Peter Duckworth, Spon Lane Iron Works, Westbromwich.
1847. Beyer, Charles F., Messrs. Beyer Peacock and Co., Gorton, near Manchester.
1847. Birley, Henry, Haigh Foundry, near Wigan.
1856. Blackburn, Isaac, Witton Park Iron Works, Darlington.
1851. Blackwell, Samuel Holden, Russell's Hall Iron Works, near Dudley.
1858. Bouch, William, Shildon Engine Works, Darlington.
1847. Bovill, George Hinton, Durnsford Lodge, near Wandsworth, Surrey, S.W.
1858. Bower, John Wilkes, Messrs. Sharp Stewart and Co., Atlas Works, Manchester.
1854. Bragge, William, Atlas Steel Works, Sheffield.
1854. Bramwell, Frederick Joseph, 35A Great George Street, Westminster, S.W.
1856. Bray, Edwin, New Dock Iron Works, Leeds.
1848. Broad, Robert, Horseley Iron Works, near Tipton.
1847. Brown, James, Jun., Messrs. James Watt and Co., Soho Foundry, near Birmingham.
1850. Brown, John, Atlas Steel Works, Sheffield.
1855. Brown, John, Mining Engineer, Barnsley, Yorkshire.

1856. Brown, John, Mining Engineer, Bank Top, Darlington.
1853. Brown, Ralph, Patent Shaft Works, Wednesbury.
1858. Burlinson, William D., Millfield Engine Works, Sunderland.
1858. Burn, Henry, Locomotive Superintendent, Danube and Black Sea Railway, Kustendjie, near Varna.
1856. Butler, Ambrose Edmund, Kirkstall Forge, Leeds.
1859. Butler, John, Old Foundry, Stanningley, near Leeds.
1859. Butler, John Octavius, Kirkstall Forge, Leeds.

1857. Cabry, Joseph, Midland Great Western Railway, Dublin.
1847. Cabry, Thomas, North Eastern Railway, York.
1847. Cammell, Charles, Cyclops Steel Works, Sheffield.
1860. Cannell, Fleetwood James, Old Park Iron Works, Wednesbury.
1860. Carbutt, Edward Hamer, Midland Railway, Locomotive Department, Derby.
1856. Carrett, William Elliott, Sun Foundry, Leeds.
1858. Carson, James Irving, Locomotive Superintendent, West Hartlepool Harbour and Railway, Stockton-on-Tees.
1849. Chamberlain, Humphrey, Sandford Works, Wareham.
1860. Chambers, Austin, North London Railway, Bow, London, E.
1852. Chellingworth, Thomas T., 12 Buckingham Street, Adelphi, London, W.C.
1857. Chrimes, Richard, Messrs. Guest and Chrimes, Brass Works, Rotherham.
1854. Clark, Daniel Kinnear, 11 Adam Street, Adelphi, London, W.C.
1859. Clark, George, Monkwearmouth Engine Works, Sunderland.
1859. Clay, William, Mersey Steel and Iron Works, Sefton Street, Liverpool.
1847. Clift, John Edward, Durnford Place, Coventry Road, Birmingham.
1860. Clunes, Thomas, Vulcan Iron Works, Worcester.
1847. Cochrane, Alexander Brodie, Woodside Iron Works, near Dudley.
1858. Cochrane, Charles, Woodside Iron Works, near Dudley.
1860. Cochrane, Henry, Ormesby Iron Works, Middlesborough.
1854. Cochrane, John, Woodside Iron Works, near Dudley.
1847. Coke, Richard George, Ankerbold, near Chesterfield.
1853. Cooper, Samuel Thomas, Leeds Iron Works, Leeds.
1860. Cope, James, Mining Engineer, Pensnett, near Dudley.
1848. Corry, Edward, 8 New Broad Street, London, E.C.
1857. Cortazzi, Francis James, Locomotive Superintendent, Great Indian Peninsula Railway, Bombay: (or care of T. D. Hornby, Exchange Buildings, Liverpool.)
1860. Coulthard, Hiram Craven, Park Iron Works, Blackburn.
1860. Cowie, David, Engine Works, Abo, Finland.
1849. Cowper, Charles, 20 Southampton Buildings, London, W.C.
1847. Cowper, Edward Alfred, 35A Great George Street, Westminster, S.W.

1853. Craig, William Grindley, 14 Cannon Street, London, E.C.
1847. Crampton, Thomas Russell, 12 Great George Street, Westminster, S.W.
1858. Crawhall, Joseph, St. Ann's Wire and Hemp Rope Works, Newcastle-on-Tyne.
1857. Criswick, Theophilus, Plymouth Iron Works, Merthyr Tydvil.
1858. Cubitt, Charles, 3 Great George Street, Westminster, S.W.

1849. Dawes, George, Milton and Elsecar Iron Works, near Barnsley, Yorkshire.
1860. Dawes, William Henry, Bromford Iron Works, Westbromwich.
1857. Deane, John Horridge, 7 Falkner Square, Liverpool.
1857. De Bergue, Charles, Strangeways Iron Works, Manchester.
1858. Dees, James, Whitehaven.
1858. Dempsey, William, 26 Great George Street, Westminster, S.W.
1859. Dixon, John, Railway Foundry, Bradford, Yorkshire.
1854. Dodds, Thomas W., Holmes Engine Works, Rotherham.
1857. Douglas, George K., Resident Engineer, Birkenhead Lancashire and Cheshire Junction Railway, Birkenhead.
1857. Dove, George, Woodbank Iron Works, Carlisle.
1856. Dudgeon, John, Sun Iron Works, Millwall, London, E.
1856. Dudgeon, William, Sun Iron Works, Millwall, London, E.
1857. Dunlop, John Macmillan, Marlborough Street, Oxford Street, Manchester.
1854. Dunn, Thomas, Windsor Bridge Iron Works, Manchester.
1860. Dyson, George, Tudhoe Iron Works, near Ferryhill.

1859. Eassie, Peter Boyd, Saw Mills, High Orchard, Gloucester.
1858. Easton, Edward, Grove Works, Southwark, London, S.E.
1856. Eastwood, James, Railway Iron Works, Derby.
1859. Egleston, Thomas, Jun., 10 Fifth Avenue, New York, United States.
1859. Elliot, George, Houghton-le-Spring, near Fence Houses.
1860. Elwell, Thomas, Messrs. Varrall Elwell and Poulot, 9 Avenue Trudaine, Paris.
1853. England, George, Hatcham Iron Works, New Cross, Surrey, S.E.
1857. Evans, John Campbell, Morden Iron Works, East Greenwich, S.E.
1848. Everitt, George Allen, Kingston Metal Works, Adderley Street, Birmingham.

1857. Fairlie, Robert Francis, 224 Gresham House, Old Broad Street, London, E.C.
1856. Fay, Charles, Lancashire and Yorkshire Railway, Carriage Department, Manchester.
1847. Fenton, James, Low Moor Iron Works, near Bradford, Yorkshire.
1854. Fernie, John, Midland Railway, Locomotive Department, Derby.
1847. Fletcher, Edward, Locomotive Superintendent, North Eastern Railway, Gateshead.

1857. Fletcher, James, Messrs. W. Collier and Co., 2 Greengate, Salford, Manchester.
1859. Fogg, Robert, 17 Park Street, Westminster, S.W.
1849. Forsyth, John C., North Staffordshire Railway, Stoke-upon-Trent.
1847. Fothergill, Benjamin, 65 Cannon Street, London, E.C.
1847. Fowler, John, 2 Queen Square Place, Westminster, S.W.
1857. Fowler, John, Jun., 28 Cornhill, London, E.C.
1847. Fox, Sir Charles, 8 New Street, Spring Gardens, London, S.W.
1859. Fraser, John, Resident Engineer, Leeds Bradford and Halifax Junction Railway, Leeds.
1853. Fraser, Joseph Boyes, Alma Place, Kenilworth.
1856. Freeman, Joseph, 22 Cannon Street, London, E.C.
1852. Froude, William, Elmsleigh, Paignton, Torquay.

1847. Garland, William S., Messrs. James Watt and Co., Soho Foundry, near Birmingham.
1848. Gibbons, Benjamin, Hill Hampton House, near Stourport.
1860. Gibbons, Benjamin, Jun., Millfield Iron Works, Westbromwich.
1856. Gilkes, Edgar, Tees Engine Works, Middlesborough.
1854. Goode, Benjamin W., St. Paul's Square, Birmingham.
1847. Goodfellow, Benjamin, Hyde Iron Works, Hyde, near Manchester.
1848. Green, Charles, Tube Works, Leek Street, Birmingham.
1858. Greenwood, Thomas, Albion Foundry, Leeds.
1857. Gregory, John, Engineer, Portuguese National Railway South of Tagus, Barriero, near Lisbon.
1860. Grice, Frederic Groom, Stour Valley Works, Spon Lane, Westbromwich.

1857. Hall, William, Bloomfield Iron Works, Tipton.
1860, Hamilton, Gilbert, Messrs. James Watt and Co., Soho Foundry, Birmingham.
1858. Harding, John, Beeston Manor Iron Works, Leeds.
1859. Harman, Henry William, Canal Street Works, Manchester.
1856. Harrison, George, Canada Works, Birkenhead.
1858. Harrison, Thomas Elliot, North Eastern Railway, Newcastle-on-Tyne.
1859. Harvey, William Beauchamp Bagnal, Engineer, H. M. Mint, Calcutta.
1858. Haswell, John A., North Eastern Railway, Locomotive Department, Gateshead.
1856. Hawksley, Thomas, 30 Great George Street, Westminster, S.W.
1848. Hawthorn, Robert, Forth Banks, Newcastle-on-Tyne.
1848. Hawthorn, William, Forth Banks, Newcastle-on-Tyne.
1859. Head, Jeremiah, Messrs. Kitson and Co., Airedale Foundry, Leeds.
1860. Head, John, Messrs. Ransomes and Sims, Orwell Works, Ipswich.

1858. Head, Thomas Howard, Teesdale Iron Works, Stockton-on-Tees.
1853. Headly, James Ind, Eagle Works, Cambridge.
1857. Healey, Edward Charles, 163 Strand, London, W.C.
1860. Heaton, George, Royal Copper Mint, Icknield Street East, Birmingham.
1858. Hedley, John, Resident Engineer, South Hetton Colliery, near Fence Houses.
1848. Hewitson, William Watson, Airedale Foundry, Leeds.
1859. Hobbs, Alfred Charles, Arlington Street, New North Road, London, N.
1858. Hodgson, Robert, North Eastern Railway, Newcastle-on-Tyne.
1852. Holcroft, James, Shut End, Brierley Hill.
1848. Homersham, Samuel Collett, 19 Buckingham Street, Adelphi, London, W.C.
1860. Hopkins, James Innes, Tees Side Iron Works, Middlesborough.
1856. Hopkinson, John, Messrs. Wren and Hopkinson, Altrincham Street, Manchester.
1858. Hopper, George, Houghton-le-Spring Iron Works, near Fence Houses.
1851. Horton, Joshua, Etna Works, Smethwick, near Birmingham.
1858. Horsley, William, Jun., Hartley Engine Works, Seaton Sluice, near North Shields.
1858. Hosking, John, Gateshead Iron Works, Gateshead.
1860. Howard, James, Britannia Works, Bedford.
1860. Howe, William, Clay Cross Coal and Iron Works, near Chesterfield.
1847. Howell, Joseph, Hawarden Iron Works, Holywell, Flintshire.
1857. Humber, William, Pancras Chambers, Pancras Lane, Bucklersbury, London, E.C.
1859. Hunt, James P., Corngreaves Iron Works, Corngreaves, near Birmingham.
1856. Hunt, Thomas, London and North Western Railway, Locomotive Department, Crewe.
1860. Hurry, Henry C., Engineer, West Midland Railway, Worcester.

1850. Ikin, Jonathan Dickson, 2 Cannon Row, Westminster, S.W.
1857. Inshaw, John, Engine Works, Morville Street, Birmingham.

1859. Jackson, Matthew Murray, Messrs. Escher Wyss and Co., Engine Works, Zurich.
1847. Jackson, Peter Rothwell, Salford Rolling Mills, Manchester.
1860. Jackson, Samuel, Cyclops Steel Works, Sheffield.
1858. Jaffrey, George William, Hartlepool Iron Works, Hartlepool.
1856. James, Jabez, 28A Broadwall, Stamford Street, Lambeth, London, S.
1855. Jeffcock, Parkin, Mining Engineer, Midland Road, Derby.
1857. Jenkins, William, Locomotive Superintendent, Lancashire and Yorkshire Railway, Miles Platting, Manchester.
1854. Jobson, John, Derwent Foundry, Derby.
1847. Jobson, Robert, Dudley.

1847. Johnson, James, Great Northern Railway, Locomotive Department, Doncaster.
1848. Johnson, Richard William, Oldbury Carriage Works, near Birmingham.
1849. Johnson, William, 166 Buchanan Street, Glasgow.
1855. Johnson, William Beckett, St. George's Iron Works, Hulme, Manchester.
1847. Jones, Edward, Old Park Iron Works, Wednesbury.
1857. Jones, John Hodgson, 26 Great George Street, Westminster, S.W.
1853. Joy, David, Messrs. C. De Bergue and Co., Strangeways Iron Works, Manchester.

1857. Kay, James Clarkson, Phœnix Foundry, Bury, Lancashire.
1857. Kendall, William, Locomotive Superintendent, Blyth and Tyne Railway, Percy Main, near North Shields.
1847. Kennedy, James, Cressington Park, Aigburth, Liverpool.
1857. Kennedy, Lieut.-Col. John Pitt, R.E., Engineer, Bombay Baroda & Central Indian Railway; 10 Liverpool Street, New Broad Street, London, E.C.
1848. Kirkham, John, 109 Euston Road, London, N.W.
1847. Kirtley, Matthew, Locomotive Superintendent, Midland Railway, Derby.
1859. Kitson, Frederick William, Monkbridge Iron Works, Leeds.
1848. Kitson, James, Airedale Foundry, Leeds.
1859. Kitson, James, Jun., Monkbridge Iron Works, Leeds.

1860. Law, David, Phœnix Iron Works, Glasgow.
1857. Laybourn, John, Isca Foundry, Newport, Monmouthshire.
1856. Laybourn, Richard, Locomotive Superintendent, Monmouthshire Railway and Canal Company, Newport, Monmouthshire.
1860. Lea, Henry, Resident Engineer, Lendal Bridge, York.
1860. Lee, John, Victoria Foundry, Litchurch, near Derby.
1857. Lees, John, Park Bridge Iron Works, Ashton-under-Lyne.
1857. Lees, Sylvester, Locomotive Superintendent, East Lancashire Railway, Bury, Lancashire.
1858. Leslie, Andrew, Iron Ship Building Yard, Hebburn Quay, Gateshead.
1856. Levick, Frederick, Cwm-Celyn Blaina and Coalbrook Vale Iron Works, near Newport, Monmouthshire.
1860. Lewis, Thomas William, Plymouth Iron Works, Merthyr Tydvil.
1856. Linn, Alexander Grainger, 2 Queen Square Place, Westminster, S.W.
1857. Little, Charles, Beehive Mills, Thornton Road, Bradford, Yorkshire.
1847. Lloyd, Sampson, Old Park Iron Works, Wednesbury.
1852. Lloyd, Samuel, Jun., Old Park Iron Works, Wednesbury.
1856. Longridge, Robert Bewick, Steam Boiler Assurance Company, New Brown Street, Market Street, Manchester.
1859. Lord, Thomas Wilks, 32 Boar Lane, Leeds.
1854. Lynde, James Gascoigne, Town Hall, Manchester.

1856. Mackay, John, Mount Hermon, Drogheda.
1859. Manning, John, Boyne Engine Works, Hunslet, Leeds.
1857. March, George, Union Foundry, Leeds.
1856. Markham, Charles, Midland Railway, Derby.
1848. Marshall, Edwin, Britannia Carriage Works, Birmingham.
1859. Marshall, William Ebenezer, Sun Foundry, Leeds.
1847. Marshall, William Prime, 81 Newhall Street, Birmingham.
1859. Marten, Edward Bindon, Stourbridge Water Works, Stourbridge.
1860. Marten, George Priestley, Messrs. Stothert and Marten, Steam Ship Works, Bristol.
1853. Marten, Henry, Parkfield Iron Works, near Wolverhampton.
1857. Martindale, Capt. Ben Hay, R.E., Under Secretary for Public Works and Commissioner for Internal Communication, Sydney, New South Wales.
1854. Martineau, Francis Edgar, Globe Works, Cliveland Street, Birmingham.
1857. Masselin, Armand, Spon Lane Glass Works, near Westbromwich.
1853. Mathews, William, Corbyn's Hall Iron Works, near Dudley.
1848. Matthew, John, Messrs. John Penn & Co., Marine Engineers, Greenwich, S.E.
1847. Matthews, William Anthony, Sheaf Works, Sheffield.
1859. May, Charles, 3 Great George Street, Westminster, S.W.
1857. May, Walter, Suffolk Works, Berkley Street, Birmingham.
1860. Mayer, Joseph, Iron Ship Builder, Linz, Austria.
1859. Maylor, William, East Indian Iron Company, Beypoor: (or care of E. J. Burgess, 8 Austin Friars, London, E.C.)
1847. McClean, John Robinson, 17 Great George Street, Westminster, S.W.
1847. McConnell, James Edward, Locomotive Superintendent, London and North Western Railway, Wolverton.
1860. McKenzie, James, Well House Foundry, Leeds.
1859. McKenzie, John, Locomotive Superintendent, West Midland Railway, Worcester.
1858. Meik, Thomas, Engineer to the River Wear Commissioners, Sunderland.
1857. Menelaus, William, Dowlais Iron Works, Merthyr Tydvil.
1857. Metford, William Ellis, Flook House, Taunton.
1847. Middleton, William, Vulcan Iron Foundry, Summer Lane, Birmingham.
1853. Miller, George Mackey, Great Southern and Western Railway, Dublin.
1847. Miller, Joseph, Mill Ellers, Dalston, near Carlisle.
1856. Mitchell, Charles, Iron Ship Building Yard, Low Walker, Newcastle-on-Tyne.
1858. Mitchell, James, Melrose Cottage, Plumstead Common, near Woolwich, S.E.
1859. Moor, William, Engineer, Hetton Colliery, Hetton, near Fence Houses.
1849. Morrison, Robert, Ouseburn Engine Works, Newcastle-on-Tyne.
1858. Mountain, Charles George, Suffolk Works, Berkley Street, Birmingham.
1857. Muntz, George Frederick, French Walls, near Birmingham.
1856. Muntz, George Henri Marc, Albion Tube Works, Nile Street, Birmingham.

1859. Murphy, James, Railway Works, Newport, Monmouthshire.
1858. Murray, Thomas H., Engine Works, Chester-le-Street, near Fence Houses.

1848. Napier, John, Vulcan Foundry, Glasgow.
1856. Napier, Robert, Vulcan Foundry, Glasgow.
1858. Naylor, William, Great Indian Peninsula Railway, 3 New Broad Street, London, E.C.
1860. Nettlefold, Joseph Henry, Screw Works, Broad Street, Birmingham.
1856. Newall, James, East Lancashire Railway, Carriage Department, Bury, Lancashire.
1858. Nichol, Peter Dale, East Indian Railway, Locomotive Department, Howrah, Calcutta: (or care of Anthony Nichol, Quay Side, Newcastle-on-Tyne.)
1851. Nixon, Charles, 3 Victoria Street, Westminster, S.W.
1850. Norris, Richard Stuart, London and North Western Railway, Engineer's Office, Liverpool.

1860. Oastler, William, Engineer, Worcester Gas Works, Worcester.
1847. Owen, William, Messrs. Sandford and Owen, Phœnix Works, Rotherham.

1859. Paquin, Jean François, Locomotive Superintendent, Madrid Saragossa and Alicante Railways, Madrid.
1860. Parkin, John, Harvest Lane Steel Works, Sheffield.
1858. Parkinson, John, Victoria Brass and Copper Works, Bury, Lancashire.
1847. Peacock, Richard, Messrs. Beyer Peacock & Co., Gorton, near Manchester.
1848. Pearson, John, Liver Iron Works, Boundary Street, Liverpool.
1859. Peet, Henry, Lancaster and Carlisle Railway, Locomotive Department, Carlisle.
1856. Perring, John Shae, Resident Engineer, East Lancashire Railway, Bury, Lancashire.
1860. Peyton, Edward, Bordesley Works, Birmingham.
1856. Piggott, George, Birmingham Heath Boiler Works, Birmingham.
1854. Pilkington, Richard, Jun., St. Helen's Iron Works, St. Helen's.
1859. Pim, Jonathan, Locomotive Superintendent, Waterford and Limerick Railway, Limerick.
1859. Pitts, Joseph, Old Foundry, Stanningley, near Leeds.
1859. Platt, John, Hartford Iron Works, Oldham.
1856. Pollard, John, Midland Junction Foundry, Leeds.
1860. Ponsonby, Edward Vincent, Engineer, West Midland Railway, Worcester.
1852. Porter, John Henderson, Iron Roof and Bridge Works, Gas Street, Birmingham.
1856. Preston, Francis, Ancoats Bridge Works, Ardwick, Manchester.
1848. Preston, Robert Berthon, 10 Abercrombie Square, Liverpool.
1855. Prideaux, Thomas Symes, 32 Charing Cross, London, S.W.

1847. Ramsbottom, John, Locomotive Superintendent, London and North Western Railway, Crewe.
1860. Ransome, Allen, Jun., Messrs. Worssam and Co., King's Road, Chelsea, London, S.W.
1859. Rennie, George Banks, 39 Wilton Crescent, Belgrave Square, London, S.W.
1856. Richards, Josiah, Ebbw Vale Iron Works, near Tredegar.
1858. Richardson, Thomas, Hartlepool Iron Works, Hartlepool.
1859. Richardson, William, Hartford Iron Works, Oldham.
1848. Robertson, Henry, Shrewsbury and Chester Railway, Shrewsbury.
1859. Robinson, John, Messrs. Sharp Stewart and Co., Atlas Works, Manchester.
1858. Robson, Jonathan, Blackwall Engine and Iron Ship Building Works, Gateshead.
1852. Rofe, Henry, Engineer, Birmingham Water Works, Paradise Street, Birmingham.
1851. Rogers, Ebenezer, Abercarn, near Newport, Monmouthshire.
1851. Rolinson, Thomas, Wellington Road, Dudley.
1853. Ronayne, Joseph P., 4 Harbour Hill, Queenstown.
1853. Ross, John, Messrs. Brown Marshalls and Co., Britannia Carriage Works, Birmingham.
1856. Rouse, Frederick, Great Northern Railway, Locomotive Department, Leeds.
1857. Routledge, William, New Bridge Foundry, Salford, Manchester.
1860. Rumble, Thomas William, Atlas Steel Works, Sheffield.
1856. Russel, Robert, Clooney Terrace, Waterside, Londonderry.
1847. Russell, John Scott, 20 Great George Street, Westminster, S.W.
1859. Ryder, John Northcote, Messrs. John Penn and Co., Marine Engineers, Greenwich, S.E.

1859. Sacré, Charles, Locomotive Superintendent, Manchester Sheffield and Lincolnshire Railway, Gorton, near Manchester.
1859. Salt, George, Saltaire, near Bradford, Yorkshire.
1848. Samuel, James, 26 Great George Street, Westminster, S.W.
1857. Samuelson, Alexander, Scott Street Foundry, Hull.
1857. Samuelson, Martin, Scott Street Foundry, Hull.
1860. Schneider, Henry William, Ulverstone Hæmatite Iron Works, Barrow, near Ulverstone.
1858. Scott, Joseph, Messrs. R. & W. Hawthorn, Forth Banks, Newcastle-on-Tyne.
1848. Scott, Michael, 26 Parliament Street, Westminster, S.W.
1857. Selby, George Thomas, Smethwick Tube Works, Birmingham.
1850. Shanks, Andrew, 6 Robert Street, Adelphi, London, W.C.
1856. Shelley, Charles Percy Bysshe, 21 Parliament Street, Westminster, S.W.
1859. Shuttleworth, Joseph, Stamp End Works, Lincoln.
1851. Siemens, Charles William, 3 Great George Street, Westminster, S.W.

1847. Sinclair, Robert, Eastern Counties Railway, Stratford, London, E.
1857. Sinclair, Robert Cooper, Tame Valley Colliery, Wilnecote, near Tamworth.
1859. Slater, Isaac, Gloucester Wagon Company, Gloucester.
1853. Slaughter, Edward, Avonside Iron Works, Bristol.
1859. Smith, Charles Frederic Stuart, Mining Engineer, Cinder Hill, near Nottingham.
1854. Smith, George, Wellington Road, Dudley.
1847. Smith, Henry, Spring Hill Works, Birmingham.
1860. Smith, Henry, Brierley Hill Iron Works, Brierley Hill.
1858. Smith, Isaac, 36 Lancaster Street, Birmingham.
1860. Smith, John, Brass Foundry, Traffic Street, Derby.
1857. Smith, Josiah Timmis, Ulverstone Hæmatite Iron Works, Barrow, near Ulverstone.
1859. Smith, Matthew, Fazeley Street Wire Mills, Birmingham.
1860. Smith, Richard, The Priory, Dudley.
1857. Smith, William, 19 Salisbury Street, Adelphi, London, W.C.
1857. Snowdon, Thomas, Stockton-on-Tees.
1859. Sokoloff, Capt. Alexander, Engineer, Russian Imperial Service, Steam Marine Department, Cronstadt.
1858. Sörensen, Bergerius, Engineer-in-Chief, Royal Norwegian Navy Department, Horten Dockyard, Norway: (or care of Messrs. Tottie and Sons, 2 Alderman's Walk, Bishopsgate Street, London, E.C.)
1859. Spencer, John Frederic, Bank Buildings, Newcastle-on-Tyne.
1853. Spencer, Thomas, Old Park Works, near Shiffnal.
1854. Spencer, Thomas, Newburn Steel Works, Newcastle-on-Tyne.
1859. Stewart, Charles P., Messrs. Sharp Stewart and Co., Atlas Works, Manchester.
1851. Stewart, John, Blackwall Iron Works, Russell Street, Blackwall, London, E.
1857. Stokes, Lingard, Locomotive Superintendent, East Indian Railway, Howrah, Calcutta.
1860. Swindell, James Evers, Parkhead Iron Works, Dudley.
1859. Swingler, Thomas, Victoria Foundry, Litchurch, near Derby.

1859. Tannett, Thomas, Victoria Foundry, Leeds.
1858. Taylor, James, Britannia Works, Cathcart Street, Birkenhead.
1858. Taylor, Thomas John, Earsdon, near Newcastle-on-Tyne.
1860. Thierry, Eugène, Inspecting Engineer, Russian Railways, 25 Place Vendôme, Paris.
1848. Thompson, Isaac, Queensferry Colliery, near Flint.
1857. Thompson, John Taylor, Messrs. R. and W. Hawthorn, Forth Banks, Newcastle-on-Tyne.

1857. Thompson, Robert, Haigh Foundry, near Wigan.
1852. Thomson, George, Crookhay Iron Works, Westbromwich.
1858. Thomson, William, Jun., Railway Foundry, Normanton.
1847. Thornton, Samuel, Bradford Street, Birmingham.
1857. Tomlinson, Joseph, Jun., Locomotive Superintendent, Taff Vale Railway, Cardiff.
1856. Tosh, George, Locomotive Superintendent, Maryport and Carlisle Railway, Maryport.
1860. Townsend, Thomas C., 17 Talbot Chambers, Shrewsbury.
1856. Truss, Thomas, Shrewsbury and Chester Railway, Carriage Department, Chester.
1859. Turner, Edwin, Bowling Iron Works, near Bradford, Yorkshire.
1849. Turton, Thomas Burdett, Sheaf Works, Sheffield.
1856. Tyler, Capt. Henry Wheetley, R.E., Railway Department, Board of Trade, Whitehall, London, S.W.

1856. Vernon, John, Iron Ship Building Yard, Brunswick Dock, Liverpool.

1856. Waddington, John, New Dock Iron Works, Leeds.
1856. Waddington, Thomas, New Dock Iron Works, Leeds.
1847. Walker, Thomas, Patent Shaft Works, Wednesbury.
1856. Waller, William, Iron Works, Dundalk.
1856. Wardle, Charles Wetherell, Boyne Engine Works, Hunslet, Leeds.
1852. Warham, John R., Iron Works, Burton-on-Trent.
1847. Weallens, William, Messrs. R. Stephenson and Co., South Street, Newcastle-on-Tyne.
1860. Weild, William, Messrs. Sharp Stewart and Co., Atlas Works, Manchester.
1857. West, Frank W. S., East Indian Railway, Calcutta.
1856. Wheeldon, Frederick R., Highfields Engine Works, Bilston.
1859. Whitham, James, Perseverance Iron Works, Kirkstall Road, Leeds.
1859. Whitham, Joseph, Perseverance Iron Works, Kirkstall Road, Leeds.
1847. Whitworth, Joseph, Chorlton Street, Manchester.
1852. Whytehead, William Keld, Engineer-in-Chief to the Government of Paraguay, 69 Cornhill, London, E.C.
1859. Wickham, Henry Wickham, M.P., Low Moor Iron Works, near Bradford, Yorkshire.
1859. Wickham, Lamplugh Wickham, Low Moor Iron Works, near Bradford, Yorkshire.
1847. Williams, Richard, Patent Shaft Works, Wednesbury.
1859. Williams, Richard Price, Great Northern Railway, Engineer's Office, King's Cross, London, N.
1850. Williams, Walter, Jun., Albion Iron Works, Westbromwich.

1856. Wilson, Edward, West Midland Railway, Worcester.
1858. Wilson, Edward Brown, 36 Parliament Street, Westminster, S.W.
1859. Wilson, George, Messrs. Cammell and Co., Cyclops Steel Works, Sheffield.
1857. Wilson, John, Spring Works, Hill Top, Westbromwich.
1852. Wilson, Joseph W., 9 Buckingham Street, Strand, London, W.C.
1857. Wilson, Robert, Bridgewater Foundry, Patricroft, near Manchester.
1860. Wilson, William, 27 Duke Street, Westminster, S.W.
1859. Winter, Thomas Bradbury, 28 Moorgate Street, London, E.C.
1858. Wood, Nicholas, Hetton Hall, Hetton, near Fence Houses.
1848. Woodhouse, Henry, London and North Western Railway, Stafford.
1851. Woodhouse, John Thomas, Midland Road, Derby.
1858. Woods, Hamilton, Messrs. Allsopp and Sons, Burton-on-Trent.
1860. Worssam, Samuel William, King's Road, Chelsea, London, S.W.
1860. Worthington, Samuel Barton, Engineer, London and North Western Railway, Lancaster.
1848. Wright, Henry, Fair Lawn Villa, Turnham Green, London, W.
1859. Wright, Joseph, Saltley Works, Birmingham.
1860. Wright, Joseph, Teesdale Iron Works, Stockton-on-Tees.
1859. Wrigley, Francis, Queen's Chambers, 5 Market Street, Manchester.
1853. Wymer, Francis W., Tyne and Continental Steam Navigation Company, Newcastle-on-Tyne.

HONORARY MEMBERS.

1848. Branson, George, Belmont Row, Birmingham.
1858. Budden, William Humphryes, Messrs. R. Stephenson and Co., South Street, Newcastle-on-Tyne.
1851. Clare, Thomas Deykin, Carr's Lane, Birmingham.
1848. Crosby, Samuel, Leek Street, Birmingham.
1850. Gwyther, Edwin, Belmont Row, Birmingham.
1857. Hawkes, William, Eagle Foundry, Broad Street, Birmingham.
1860. Hutchinson, William, West Hartlepool.
1858. Lawton, Benjamin C., Grainger Street, Newcastle-on-Tyne.
1860. Manby, Cordy, New Street, Dudley.
1856. Marshall, John, Low Moor Iron Works, near Bradford, Yorkshire.
1848. Peto, Sir Samuel Morton, Bart., 9 Great George Street, Westminster, S.W.
1856. Pettifor, Joseph, Midland Railway, Derby.
1859. Sherriff, Alexander Clunes, General Manager, West Midland Railway, Worcester.
1856. Singleton, William, Dock Street, Leeds.
1848. Warden, William Marston, Edgbaston Street, Birmingham.
1858. Waterhouse, Thomas, Claremont Place, Sheffield.

HONORARY LIFE MEMBERS.

1849. Hodgkinson, Eaton, Eaglesfield House, Great Clowes Street, Higher Broughton, Manchester.

1859. Leather, John Towlerton, Leventhorpe Hall, near Leeds.

GRADUATES.

1850. Glydon, George, Spring Hill Tube and Metal Works, Eyre Street, Birmingham.

1851. Potts, John Thorpe, 4 Crescent Place, The Grove, Camberwell, Surrey, S.

PROCEEDINGS.

25 January, 1860.

The Thirteenth Annual General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 25th January, 1860; Joseph Whitworth, Esq., Vice-President, in the Chair, succeeded by James Kennedy, Esq., President.

The Minutes of the last General Meeting were read and confirmed.

The Secretary then read the following

ANNUAL REPORT OF THE COUNCIL.

1860.

The Council have great pleasure, on this Thirteenth Anniversary of the Institution, in congratulating the Members on the very satisfactory position and continued progress of the Institution.

The Financial statement of the affairs of the Institution for the year ending 31st December, 1859, shows a balance in the Treasurer's hands of £713 16*s.* 11*d.*, after the payment of the accounts due to that date. The Finance Committee have examined and checked the receipts and payments of the Institution for the last year, 1859, and report that the following Balance Sheet rendered by the Treasurer is correct.

(*See Balance Sheet appended.*)

The Council report with great satisfaction the continued increase in the number of Members that has taken place during the last year; the total number of all classes for the year being 391, of whom 17 are Honorary Members, and 2 are Graduates.

The following deceases of Members of the Institution have occurred during the past year, 1859:—

William Hartree, . . .	London.
François Laurent, . . .	Paris.
Robert Stephenson, . . .	London.
James Taylor, ...	Leeds.
William Williams, . . .	Crewe.
Joseph Wright, ...	Birmingham.

On this occasion the Council cannot but refer with deep regret to the great loss suffered by the profession and the country at large during the past year, in the death of Mr. Robert Stephenson, the second President of this Institution, in which office he succeeded his father, the late George Stephenson, and took a warm interest in promoting the advance and prosperity of the Institution.

The Council have the pleasure of acknowledging the following Donations to the Library of the Institution during the past year, and expressing their thanks to the donors for the valuable and acceptable additions they have presented. The Council wish to urge especially on the attention of the Members the important advantage to the Institution of obtaining a good collection of Engineering Books, Drawings, and Models, for the purpose of reference by the Members personally or by correspondence; and they trust that this highly desirable object will be supported by the Members generally, that by their united aid it may be efficiently accomplished.

LIST OF DONATIONS TO THE LIBRARY.

Reports of the Chief Commissioner for Railways on the Internal Communications of New South Wales; from Capt. Martindale, R.E.

Report of the Commissioner of Patents, United States, 1856; 3 vols.

Report of the Hot Blast Trial, 1843; from Mr. James B. Neilson.

Papers on Mechanical Subjects, by Joseph Whitworth; from the Author.

On the Resistance of Glass Globes and Cylinders to Collapse, by William Fairbairn and Thomas Tate; from Mr. William Fairbairn.

On the Rise and Progress of Civil and Mechanical Engineering, by William Fairbairn; from the Author.

On the Conveyance of Coals Underground in Coal Mines, by Nicholas Wood; from the Author.

On High Speed Steam Navigation, by Robert Armstrong; from the Author.

On Machinery for Shearing, Punching, Rivetting, and Forging, by T. S. Sawyer; from the Author.
Collection of Engineering Drawings, second part; from the École Impériale des Ponts et Chaussées.
Proceedings of the Institution of Civil Engineers; from the Institution.
Transactions of the French Institution of Civil Engineers; from the Institution.
Transactions of the North of England Institute of Mining Engineers; from the Institute.
Transactions of the Institution of Engineers in Scotland; from the Institution.
Proceedings of the South Wales Institute of Engineers; from the Institute.
Transactions of the Royal Scottish Society of Arts; from the Society.
Journal of the Society of Arts; from the Society.
The Engineer; from the Editor.
The Mechanics' Magazine; from the Editor.
The Civil Engineer and Architect's Journal; from the Editor.
The London Journal of Arts; from the Editor.
The Artizan Journal; from the Editor.
The Practical Mechanic's Journal; from the Editor.
The Mining Journal; from the Editor.
The Railway Record; from the Editor.
The Steam Shipping Journal; from the Editor.

The Council have great satisfaction in referring to the number of Papers that have been brought before the meetings during the past year, and the practical value and interest of many of the communications, which form a valuable addition to the Proceedings of the Institution. The Council request the special attention of the Members to the importance of their aid and co-operation in carrying out the objects of the Institution and maintaining its advanced position, by contributing papers on Engineering subjects that have come under their observation, and communicating the particulars and results of executed works and practical experiments that may be serviceable and interesting to the Members; and the Council invite communications upon the subjects in the list appended, and other subjects advantageous to the Institution.

The following Papers have been read at the meetings during the last year :—

On the Progressive application of Machinery to Mining Purposes; by Mr. Thomas John Taylor, of Earsdon, Newcastle-on-Tyne.

Description of a Dry-Clay Brick-Making Machine; by Mr. Benjamin Fothergill, of Manchester.

Description of the Pumping Engine at the Newcastle Water Works; by Mr. Robert Morrison, of Newcastle-on-Tyne.

On the construction of Hot Blast Ovens for Iron Furnaces; by Mr. Henry Marten, of Wolverhampton.

On a Marine Engine Governor; by Mr. Peter Jensen, of Copenhagen.

On the application of the Decimal System of Measurement to Mechanical Engineering Work, &c.; by Mr. John Fernie, of Derby.

On File-Cutting Machinery; by Mr. Thomas Greenwood, of Leeds.

On the Relative Economy and Durability of various classes of Stationary Steam Boilers; by Mr. Robert B. Longridge, of Manchester.

Description of a Direct-Acting Steam Crane; by Mr. Robert Morrison, of Newcastle-on-Tyne.

Description of a new Steam Pressure Gauge; by Mr. Alexander Allan, of Perth.

Description of Haste's improved Safety Valve for steam boilers; by Mr. William Naylor, of London.

On the application of Superheated Steam in Marine Engines; by the President, John Penn, Esq.

Description of Fryer's Apparatus for filling Locomotive Tenders with Water; by Mr. James Fenton, of Low Moor.

On the Construction and Durability of Steam Boilers; by Mr. Benjamin Goodfellow, of Hyde.

On Increased Break Power for stopping railway trains; by Mr. Alexander Allan, of Perth.

Description of a Steam Crane; by Mr. J. Campbell Evans, of Greenwich.

Description of Oates' Brick-Making Machine; by Mr. John E. Clift, of Birmingham.

Description of a new construction of High Pressure Steam Boiler; by Mr. J. Frederic Spencer, of London.

The Council have particular pleasure in referring to the very successful and interesting Provincial Meeting of the Institution in Leeds in the autumn of last year, and in expressing their special thanks to the Local Committee and the Honorary Local Secretary, Mr. W. E. Marshall, for the excellent and spirited reception that was given to the Members of the Institution on that occasion; and the Council look forward with great satisfaction to the important advantages arising from the establishment of these Annual Provincial

Meetings, from the facilities afforded by them for the personal communication of the Members in different districts of the country, and the opportunities of visiting the important Engineering Works that are so liberally thrown open to their inspection on those occasions.

The President, Vice-Presidents, and five of the Members of the Council in rotation, will go out of office this day, according to the rules of the Institution; and the ballot will be taken at the present annual meeting for the election of the Officers and Council for the ensuing year.

SUBJECTS FOR PAPERS.

Steam Engine Boilers, particulars of construction—form and extent of heating surface—relative value of radiant surface in effect and economy—cost—consumption of fuel—evaporation of water—pressure of steam—density and heat of steam—superheated steam, simple or mixed with common steam—pressure gauges—safety valves—water gauges—explosion of boilers, and means of prevention—effects of heat on the metal of boilers, low pressure and high pressure—steel boilers—incrustation of boilers, and means of prevention—evaporative power and economy of different kinds of fuel, coal, wood, charcoal, peat, patent coal, and coke—moveable grates, and smoke-consuming apparatus, facts to show the best plan, and results of working—plans for heating feed water—mode of feeding—circulation of water.

Steam Engines—expansive force of steam, and best means of using it—power obtained by various plans—comparison of double and single cylinder engines—combined engines—compound cylinder engines—comparative advantages of direct-acting and beam engines—engines for manufacturing purposes—horizontal and vertical—condensing and non-condensing—injection and surface condensers—air pumps—governors—valves, bearings, &c.—improved expansion gear—indicator diagrams from engines, with details of useful effect, consumption of fuel, &c.—contributions of indicator diagrams for reference in the Institution.

Pumping Engines, particulars of various constructions—Cornish engines, beam engines with crank and flywheel, direct-acting engines with and without flywheel—size of steam cylinder and degree of expansion—number and size of pumps, and strokes per minute—speed of piston—pressure upon pump—effective horse power and duty—comparison of double-acting and single-

acting pumping engines—construction of pumps—plunger pumps—bucket pumps—particular details of different valves—india-rubber valves, durability and results of working—diagrams of lift of valves—application of pumps—fen-draining engines—comparative advantages of scoop wheels and centrifugal pumps, lifting trough, &c.

Blast Engines, best kind of engine—size of steam cylinder, strokes per minute, and horse power—details of boilers—size of blowing cylinder, and strokes per minute—pressure of blast, and means of regulation—construction of valves—improvements in blast cylinders—rotary blowing machines—indicator diagrams from air main and steam cylinder.

Marine Engines, power of engines in proportion to tonnage—different constructions of engines, double-cylinder engines, trunk engines—use of steam jackets—dynamical effect compared with indicator diagrams—comparative economy and durability of different boilers, tubular boilers, flat-flue boilers, &c.—brine pumps, and means of preventing deposit—salinometers—weight of machinery and boilers—kind of paddle wheels—speed obtained in British war steamers, in British merchant steamers, and in Foreign ditto, with particulars of the construction of engines with paddle wheels, &c.—screw propellers, particulars of different kinds, improvements in form and position, number of arms, material, means for unshipping, bearings, horse power applied, speed obtained, section of vessel—governors and storm-governors.

Rotary Engines, particulars of construction and practical application—details of results of working.

Locomotive Engines, express, passenger, and luggage engines—particulars of construction, details of experiments, and results of working—consumption of fuel—use of coal—consumption of smoke—heating surface, length and diameter of tubes—steel tubes—experiments on size of tubes and blast pipe—construction of pistons, valve gear, expansion gear, &c.—indicator diagrams—expenses of working and repairs.

Agricultural Engines, details of construction and results of working—duty obtained—application of machinery and steam power to agricultural purposes—barn machinery—field implements—traction engines, particulars of performance and cost of work done.

Caloric Engines—engines worked by Gas, Gun-cotton, or other explosive compounds—Electro-magnetic engines—particulars and results.

Hydraulic Engines, particulars of application and working—pressure of water—construction and arrangement of valves, relief valves—construction of joints—hydraulic rams.

Water Wheels, particulars of construction and dimensions—form and depth of buckets—head of water, velocity, percentage of power obtained—turbines, construction and practical application, power obtained, comparative effect and economy.

WIND MILLS, particulars of construction—number of sails, surface and form of sails—velocity, and power obtained—average number of days' work per annum.

CORN MILLS, particulars of improvements — power employed — application of steam power—results of working with an air blast and ring stones—crushing by rolls before grinding—advantages of regularity of motion.

SUGAR MILLS, particulars of construction and working—results of the application of the hydraulic press in place of rolls—application of steam and water for extracting the last portion of saccharine matter — construction and working of evaporating pans.

OIL MILLS, facts relating to the construction and working, by stampers, by screw presses, and by hydraulic presses—particulars of crushing rollers and edge stones.

COTTON MILLS, information respecting the construction and arrangement of the machinery -- power employed, and application of power—cotton presses, mode of construction and working, power employed — improvements in spinning and carding machinery, &c.

CALICO-PRINTING AND BLEACHING MACHINERY, particulars of improvements.

WOOL MACHINERY, carding, combing, roving, spinning, &c.

FLAX MACHINERY, manufacture of flax and other fibrous materials, both in the natural length of staple and when cut.

SAW MILLS, particulars of construction—mode of driving—power employed—particulars of work done—best speeds for vertical and circular saws—form of saw teeth—saw mills for cutting ship timbers—veneer saws—endless band saws.

WOOD-WORKING MACHINES, morticing, planing, rounding, and surfacing—copying machinery.

LATHES, PLANING, BORING, AND SLOTTING MACHINES, &c., particulars of improvements—description of new self-acting tools—engineers' tools—files and file-cutting machinery.

ROLLING MILLS, improvements in machinery for making iron and steel—mode of applying power—use of steam hammers—piling of iron—plates—fancy sections—arrangement and speed of rolls—length of bar rolled—manufacture of rolled girders.

STEAM HAMMERS—friction hammers—air hammers.

RIVETTING, PUNCHING, AND SHEARING MACHINES, worked by steam or hydraulic pressure—direct-acting and lever machines.

STAMPING AND COINING MACHINERY, particulars of improvements, &c.

PAPER-MAKING AND PAPER-CUTTING MACHINES, new materials and results.

PRINTING MACHINES, particulars of improvements, &c.

WATER PUMPS, facts relating to the best construction, means of working, and application—velocity of piston—construction, lift, and area of valves.

AIR PUMPS, facts relating to the best construction, means of working, and application—velocity of piston—construction, lift, and area of valves.

HYDRAULIC PRESSES, facts relating to the best construction, means of working, and application—economical limit of pressure.

ROTARY AND CENTRIFUGAL PUMPS, ditto ditto ditto

FIRE ENGINES, hand and steam, ditto ditto ditto

SLUICES AND SLUICE COCKS, worked by hand or hydraulic power, ditto

CRANES, steam cranes, hydraulic cranes, pneumatic cranes, travelling cranes.

LIFTS for raising railway wagons—hoists for warehouses—safety apparatus.

TOOTHED WHEELS, best construction and form of teeth—results of working—power transmitted—method of moulding—strength of iron and wood teeth.

DRIVING BELTS AND STRAPS, best make and material, leather, guttapercha, rope, wire, chain, &c.—comparative durability, and results of working—power communicated by certain sizes—frictional gearing, construction and driving power obtained—friction clutches—shafting and couplings.

DYNAMOMETERS, construction, application, and results of working.

STRENGTH OF MATERIALS, facts relating to experiments, and general details of the proof of girders, &c.—girders of cast and wrought iron, particulars of different constructions, and experiments on them—rolled girders—best forms and proportions of girders for different purposes—best mixture of metal—mixtures of wrought iron with cast.

DURABILITY OF TIMBER of various kinds—best plans for seasoning and preserving timber and cordage—results of various processes—comparative durability of timber in different situations—experiments on actual strength of timber.

CORROSION OF METALS by salt and fresh water, and by the atmosphere, &c.—facts relating to corrosion, and best means of prevention—means of keeping ships' bottoms clean—galvanic action, nature, and preventives.

ALLOYS OF METALS, facts relating to different alloys—use of aluminium.

FRICTION OF VARIOUS BODIES, facts relating to friction under ordinary circumstances—facts on increase of friction by reduction of surface in contact—friction of iron, brass, copper, tin, wood, &c.—proportion of weight to rubbing surface—best forms of journals, and construction of axleboxes—wood bearings—water axleboxes—lubrication, best materials, means of application, and results of practical trials—best plans for oil tests—friction breaks.

IRON ROOFS, particulars of construction for different purposes—durability in various climates and situations—comparative cost, weight, and durability—roofs for slips of cast iron, wrought iron, timber, &c.—best construction, form, and materials—details of large roofs, and cost.

FIRE-PROOF BUILDINGS, particulars of construction—most efficient plan—results of trials.

CHIMNEY STACKS of large size—particulars, form, mode of building, cheapest construction, &c.—force of draught, and temperature.

BRICKS, manufacture, durability, and strength—hollow bricks, fire bricks, and fire clay—perforated bricks, cost of manufacture, and advantages—dry clay bricks—machines for brick making—burning of bricks.

GAS WORKS, best form, size, and material for retorts—construction of retort ovens—quantity and quality of gas from different coals—oil gas, cheapest mode of making—water gas, &c.—improvements in purifiers, condensers, and gasholders—wet and dry gas meters—self-regulating meters—pressure of gas, gas exhauster—gas pipes, strength and durability, and construction of joints—proportionate diameter and length of gas mains, and velocity of the passage of gas—experiments on ditto, and on the friction of gas in mains, and loss of pressure.

WATER WORKS, facts relating to water works—application of power, and economy of working—proportionate diameter and length of pipes—experiments on the discharge of water from pipes, and friction through pipes—strength and durability of pipes, and construction of joints—penetration of frost in different climates—relative advantages of stand pipes and air vessels—water meters, construction and working.

WELL SINKING, AND ARTESIAN WELLS, facts relating to—boring tools, construction and mode of using.

TUNNELLING MACHINES, particulars of construction and results of working.

COFFER DAMS AND PILING, facts relating to the construction—cast iron sheet piling.

PIERS, fixed and floating, and pontoons, ditto ditto

PILE DRIVING APPARATUS, particulars of improvements—use of steam power—particulars of working—weight of ram and height of fall, total number of blows required—vacuum piles—compressed air system—screw piles.

DREDGING MACHINES, particulars of improvements—application of dredging machines—power required and work done.

DIVING BELLS AND DIVING DRESSES, facts relating to the best construction.

LIGHTHOUSES, cast iron and wrought iron, ditto ditto

SHIPS, iron and wood—details of construction—lines, tonnage, cost per ton—water ballast.

MINING OPERATIONS, facts relating to mining—means of ventilating mines—use of ventilating machinery—safety lamps—lighting mines by gas—drainage of mines—sinking pits—mode of raising materials—safety guides—winding machinery—underground conveyance—mode of breaking, pulverising, and sifting various descriptions of ores.

BLASTING, facts relating to blasting under water, and blasting generally—use of gun-cotton, &c.—effects produced by large and small charges of powder—arrangement of charges.

Blast Furnaces, consumption of fuel in different kinds—burden, make, and quality of metal—pressure of blast—horse power required—economy of working—improvements in manufacture of iron—comparative results of hot and cold blast—increased temperature of blast—construction and working of hot blast ovens—pyrometers—means and results of application of waste gases.

Puddling Furnaces, best forms and construction — worked with coal, charcoal, &c.

Heating Furnaces, best construction—consumption of fuel, and heat obtained.

Converting Furnaces, construction of furnaces—manufacture of steel—casehardening, &c.—converting materials employed.

Smiths' Forges, best construction—size and material—power of blast—hot blast, &c.—construction of tuyeres.

Smiths' Fans, and Fans generally, best construction, form of blades, &c.—facts relating to power employed and percentage of effect produced—pressure and quantity of air discharged—size and construction of air mains.

Coke and Charcoal, particulars of the best mode of making, and construction of ovens, &c.—evaporating power of different varieties.

Railways, construction of permanent way — section of rails, and mode of manufacture—mode of testing rails—experiments on rails, deflection, deterioration, and comparative durability—material and form of sleepers, size, and distances—improvements in chairs, keys, and joint fastenings—permanent way for hot climates.

Switches and Crossings, particulars of improvements, and results of working—advantages obtained by steeling points and tongues.

Turntables, particulars of various constructions and improvements — engine turntables.

Signals for stations and trains, and self-acting signals.

Electric Telegraphs, improvements in construction and insulation—underground and submarine cables—mode of laying.

Railway Carriages and Wagons, details of construction—proportion of dead weight.

Breaks for carriages and wagons, best construction—self-acting breaks—continuous breaks.

Buffers for carriages, &c., and station buffers — different constructions and materials.

Springs for carriages, &c.—buffing, bearing, and draw springs—range, and deflection per ton—particulars of different constructions and materials, and results of working.

Railway Wheels, wrought iron, cast iron, and wood—particulars of different constructions, and results of working—comparative expense and durability—wrought iron and steel tyres, comparative economy and results of working—mode of fixing tyres—solid wrought iron wheels.

RAILWAY AXLES, best description, form, material, and mode of manufacture—comparison of solid and hollow axles.

The communications should be written on foolscap paper, on one side only of each page, leaving a clear margin on the left side for binding, and they should be written in the third person. The drawings illustrating the paper should be on a large scale and strongly coloured, so as to be clearly visible to the meeting at the time of reading the paper; or enlarged diagrams should be added for the illustration of any particular portions: the scale of each drawing to be marked upon it.

INSTITUTION OF MECHANICAL ENGINEERS.

BALANCE SHEET.

For the year ending 31*st December*, 1859.

Cr.	£	s.	d.
By Balance 31st December, 1858	425	13	8
,, Subscriptions from 26 Members in arrear	78	0	0
,, ditto from 1 Graduate in arrear	2	0	0
,, ditto from 328 Members for 1859	984	0	0
,, ditto from 2 Graduates for 1859	4	0	0
,, Entrance Fees from 70 New Members	140	0	0
,, Subscriptions from 4 Members in advance for 1860	12	0	0
,, ditto from 1 Life Member	30	0	0
,, Sale of Extra Reports	12	13	0
,, Interest from Bank	12	13	0
	£1700	19	8

Dr.	£	s.	d.	£	s.	d.
To Printing and Engraving Reports of Proceedings	313	8	0			
Less Authors' copies of papers, repaid	43	16	6	269	11	6
,, Stationery and Printing				57	7	3
,, Office Expenses and Petty Disbursements				27	2	7
,, Expenses of Meetings				10	12	10
,, Fittings, &c.					13	6
,, Travelling Expenses				15	16	3
,, Parcels				3	2	11
,, Postages				36	5	11
,, Salaries				450	0	0
,, Rent and Taxes				116	10	0
,, Balance 31st December, 1859				713	16	11
				£1700	19	8

(Signed) EDWARD JONES, JOHN FERNIE, Finance Committee.

25th January, 1860.

The CHAIRMAN moved that the Report of the Council be received and adopted, which was passed.

The CHAIRMAN announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following Officers and Members of Council were duly elected for the ensuing year :—

PRESIDENT.

JAMES KENNEDY, . . .	Liverpool.

VICE-PRESIDENTS.

SIR WILLIAM G. ARMSTRONG, .	Newcastle-on-Tyne.
JAMES FENTON, . . .	Low Moor.
BENJAMIN FOTHERGILL, . .	Manchester.
HENRY MAUDSLAY, . . .	London.
JOHN PENN, ...	London.
JOSEPH WHITWORTH, . .	Manchester.

COUNCIL.

In addition to the ten Members remaining in office.

EDWARD A. COWPER, . .	London.
JOHN FERNIE, . . .	Derby.
SAMPSON LLOYD, . . .	Wednesbury.
C. WILLIAM SIEMENS, . .	London.
EDWARD WILSON, . . .	Worcester.

TREASURER.

HENRY EDMUNDS, . . .	Birmingham.

SECRETARY.

WILLIAM P. MARSHALL, . .	Birmingham.

The following New Members were also elected :—

MEMBERS.

JOHN BARCLAY, . . .	Bradford.
AUSTIN CHAMBERS, . . .	London.
GEORGE DYSON, . . .	Ferryhill.
ALEXANDER GASSE, . . .	Worcester.
JAMES HOWARD, . . .	Bedford.
HENRY C. HURRY, . . .	Worcester.

David Law, . . .	Glasgow.
John Smith, ...	Derby.
Eugene Thierry, . . .	Newport, Mon.
Samuel Barton Worthington, .	Lancaster.
Joseph Wright, . . .	Stockton-on-Tees.

The Chair was then taken by the President elect, James Kennedy, Esq., who returned his best thanks to the Members for the honour they had done him in electing him to the office of President of the Institution; he said he felt a great interest in the welfare of the Institution, having been a member from the commencement, and his best exertions would be devoted to promote its interests and success.

The following paper was then read:—

DESCRIPTION OF AN IMPROVED GAS METER.

By Mr. ALEXANDER ALLAN, of Perth.

In the ordinary construction of wet Gas Meters the accuracy of measurement depends on a true water level being constantly maintained in the meter; and as there is a continual waste of water from evaporation, independent of any leakage or abstraction, this waste must be compensated for in order to prevent the measurement being rendered incorrect. Hitherto the gas meters in common use have been made to register 5 per cent. against the consumer in the first instance, and afterwards by gradual waste of the water to register up to 5 per cent. in his favour, so as to give a correct result on the average. By a recent act of parliament it is now provided that no meter shall receive the government inspection stamp which is capable of registering more than 2 per cent. against the consumer or 3 per cent. in his favour, thus allowing a margin of 5 per cent. for error of measurement. In other standards of measure however no such allowance is made on either side; and accordingly in the improved gas meter forming the subject of the present paper the writer's object has been to provide the means of practically compensating for the gradual waste of water, so as to obtain a meter that will continue to measure correctly under all circumstances and thereby require only about one tenth of the customary inspection. This is accomplished by means of a pneumatic fountain forming the usual square front of the meter, by which the water level in the meter is maintained constantly at the correct height.

Figs. 1, 2, and 3, Plate 1, are vertical sections of the improved meter. The square front of the meter is raised so as to form the supply fountain A, which may be of any convenient size: as shown in the drawing it is arranged to hold in suspension about 840 cubic

inches of water to compensate for waste. The fountain A communicates with the drum case B by means of the hole C. The dip pipe D is open at the top to the gas space in the meter B, Fig. 3, and passing through the partition descends into the fountain A to the water level E, at which height the water is to be maintained.

The action of this fountain is shown by the diagram, Fig. 7, Plate 2. The fountain consists of an air-tight chamber A, communicating with the vessel B through the pipe C fitted with a stopcock. The dip pipe D descends in the chamber A to the level at which the water is required to stand in the vessel B. When the fountain A has been filled with water the stopcock C is opened and the water rises in the vessel B to the level of the bottom of the dip pipe D; at this level it remains stationary in the vessel B, while a supply of water is held suspended in the fountain A. The dip pipe D contains no water, being open to the atmosphere; and there is thus the same atmospheric pressure on the surface of the water at the bottom of the dip pipe as on the surface of the water in the vessel B, causing them both to stand at the same level, like different portions of the same level water surface. The action of the fountain in maintaining the true water level in the vessel B is now seen by opening the waste cock F allowing the water to run to waste; a bubble of air then emerges from the bottom of the dip pipe D and rises into the fountain A, allowing a small quantity of water to pass from the fountain into the vessel B exactly equal in amount to the quantity run to waste. This action continues as long as there is any waste, preserving constantly the true water level in the vessel B, whatever may be the rate at which the waste takes place. This method of maintaining a true water level, depending solely upon the equilibrium of pressure at the bottom of the dip pipe and on the surface to be maintained at the true level, is entirely independent of any moving mechanism; hence any apparatus constructed on this principle will be certain of action and not liable to become deranged.

In applying this fountain to the gas meter, as shown in Plate 1, the only difference from the model is that the surface of the water is pressed on by the gas instead of being open to the atmosphere, the dip pipe D being open at the top into the gas space of the meter B, as

previously described; so that there is the same pressure on the surface of the water at the bottom of the dip pipe as on the water in the body of the meter, and the water cannot rise in the dip pipe D. Hence when the least quantity of water is withdrawn from the meter B by evaporation or otherwise, a bubble of gas will emerge from the bottom of the dip pipe D and rise into the fountain A, thus allowing exactly the same quantity of water to pass from the fountain A through the hole C into the meter B, which at once restores the true water level. This action will continue as long as there is any water in the fountain A to supply the waste; and the float G is arranged to close the inlet valve H and shut off the gas when the supply of water in the fountain becomes exhausted, so that the meter can never register incorrectly whilst gas is passing through it.

The dip pipe D cannot cause any accumulation of water in the meter above the proper level; but should this occur through any other cause, an overflow pipe I is fixed so that the meter cannot be overfilled. The overflow pipe I is brought forwards in advance of the dip pipe D, so that if the meter be tilted forwards with the view of making it register less than the quantity of gas consumed by lowering the mean water level inside the meter, the water flows out of the drum case B into the waste water box K, and intercepts the passage of the gas by closing the orifice of the pipe L leading to the interior of the drum. Should this abstraction of water from the meter be continued by taking out the plug M and allowing the water to escape through it, the dip pipe D will come into action and supply the water from the fountain A till the latter is empty, when the float G will fall and close the valve H; and the meter must be restored to its proper level position before gas can be obtained through it. The abstraction of gas from the waste water box K is also prevented by the partition N and the elongation of the tube M.

The supply fountain A can be refilled at any time without interfering with the action of the meter, through the filling tube O which descends below the bottom of the dip pipe D; and the gas that may have accumulated in the upper part of the fountain chamber A above the water escapes through the exhaust pipe P into the meter B; the bottom of the pipe P is effectually closed

against a return of gas by being submerged a little below the true water level E. The hole C communicating between the fountain A and the drum case B requires to be bushed with block tin in cast iron meters, to prevent oxidation by the passage of water through it.

Figs. 4 and 5, Plate 2, show a simpler modification of the meter, in which the inlet pipe L leading into the drum is made to act also as the overflow pipe, so that in the event of the meter being overfilled, so as to register against the consumer, the surplus water overflows into the waste water box K. In this instance a fraudulent abstraction of gas from the waste water box K is prevented by the pipes M and N placed at right angles, the vertical pipe N dipping down sufficiently far to prevent the water being forced out by any pressure of gas adopted in practice.

In reference to the position and use of the exhaust pipe P, Figs. 1 and 4, by which the gas accumulated in the fountain A escapes into the meter when the fountain is being refilled with water, it may be remarked that if the dip pipe D should become accidentally obstructed the water level inside the meter cannot fall below the bottom of the exhaust pipe P; for as soon as it falls low enough to uncover the bottom of the pipe, gas will pass up through the pipe into the top of the fountain A and allow enough water to flow from the fountain to bring up the water to the level of the bottom of the exhaust pipe P. Fig. 6 shows the exhaust pipe P extended from the fountain to the back of the drum case B, and there made to dip slighly below the water line. This arrangement has the advantage of entirely preventing the meter from being tilted forward; for if this is attempted in order to make the meter register against the company, the orifice of the exhaust pipe at the back of the meter becomes uncovered and gas passes into the fountain, allowing a compensating supply of water to pass into the meter, thus entirely preventing fraud by tilting. The exhaust pipe P may be employed in this manner either by itself or in combination with the overflow pipe I, Fig. 2, previously described. By determining the depth to which the exhaust pipe is submerged at the back of the meter below the true water level, the limit of tilting may be fixed, so as to allow

of any small accidental inclination of the surface on which the meter has to stand; while gas cannot be obtained through it if tilted designedly beyond this limit. Although the exhaust pipe P will thus compensate to a certain degree for waste in the event of the dip pipe D being obstructed, it is not intended to be employed in place of the dip pipe; for owing to capillary attraction and the impurities floating on the surface of the water in the drum case, the exhaust pipe P will not act with anything like the accuracy of the dip pipe for maintaining the true water level; and the exhaust pipe is intended only for its proper use as an essential for filling the fountain, and also to prevent fraudulent tilting and to limit the inclination at which the meter may stand when the surface on which it is placed is not level.

As to the length of time that the fountain will serve to maintain the true water level without requiring refilling, if the evaporation of water from the meter be taken at 1 cubic inch per 1000 cubic feet of gas, about double the ordinary rate of evaporation, the supply of water in the fountain being 840 cubic inches will preserve the water level unaltered during a consumption of nearly 1 million cubic feet of gas, or some years' consumption of such a meter as shown in the drawings, without requiring any attention during that time.

Mr. J. E. Clift thought the plan of meter was a very efficient and satisfactory one for the purpose of maintaining the required accuracy of measurement, and it was an important and valuable improvement, as the construction was so simple and free from all parts liable to the objection of getting out of order or impeding the action of the meter. He had seen one of these meters tested, and it preserved accuracy of measurement under all circumstances, within the limits allowed by the parliamentary regulations; and there was no difficulty in making any number of the meters to work with equal accuracy. In the models that were shown the action was illustrated by two surfaces of water, both exposed to the atmosphere and having a communication below, preserving consequently the same level

of surface in both; and in the meter the only difference was that the two surfaces were exposed to the pressure of the gas instead of the atmosphere.

Mr. C. W. Siemens had known several other plans tried for the purpose of maintaining the correct water level in gas meters, and it was important to obtain a really trustworthy meter that could be relied upon to continue correct for a long period without attention. One of the plans had a small wheel turned by the meter, lifting drops of water continuously to maintain the water in the meter up to the required level, the surplus water running back into the supply reservoir; the ordinary bird-fountain had also been tried before, but had not proved successful. He was much struck with the ingenuity displayed in the present plan in getting so simple a principle to accomplish the object, without involving the necessity for any moving parts or machinery; and the pressure of gas being the same on both of the water surfaces, their level was undisturbed by any variation of pressure. The arrangement for preventing the measurement being affected by tilting the meter was also a simple one; and the several precautions in the construction of the meter rendered it very complete.

Mr. J. E. Clift remembered a trial being made of the bird-fountain many years ago for maintaining a uniform water level in a gas meter, but it could not be made to answer at the time and had to be abandoned. The present plan had however proved quite successful at once; the water was gradually and regularly supplied to the meter, without any risk of the steadiness of the gas lights being affected by disturbance or oscillation of the water in the drum case; and it was a great advantage that no wheelwork or valves were employed, the regulating apparatus consisting only of open pipes. Many self-adjusting meters had been contrived lately, in consequence of the requirements of the recent act; but all those involving machinery, however accurate and good the workmanship might be, were inevitably liable to objection from risk of causing some obstruction to the free rotation of the drum, by their motion becoming impeded through corrosion or incrustation, since any mechanical contrivance had to be driven by the drum itself. The new meters contained no machinery, and were therefore not liable to give any trouble in this way; he

understood they were being made for general use in Scotland and also in Birmingham. The error in measurement by the ordinary meters, though a margin of 5 per cent. on both sides had been allowed as stated in the paper, often exceeded that amount considerably, sometimes to the extent of nearly ten times as much; and since gas had now become a necessary of life, it was as necessary to have a correct measure of its consumption as in the case of water and other articles; and a meter that satisfactorily accomplished this must certainly be considered a great boon.

The Chairman thought the meter described in the paper was a simple and ingenious contrivance, which appeared likely to prove thoroughly satisfactory in ensuring permanent accuracy of measurement; he proposed a vote of thanks to Mr. Allan for his paper, which was passed.

The following paper was then read:—

ON THE APPLICATION OF SUPERHEATED STEAM.

By Mr. JOHN N. RYDER, of London.

The important subject of Superheated Steam has been brought under the notice of the Members by the interesting paper read by the President at the Leeds Meeting last year. Since then rapid progress has been made, and an evident desire manifested by many large consumers of steam power to learn more upon the subject with a view to its adoption. Yet hitherto much indecision has been unnecessarily caused in many cases, by erroneous views as to danger in the application of superheated steam and doubtful economy in its use. It therefore becomes necessary that these questions be determined by an investigation of the subject, in order to arrive at trustworthy conclusions. The writer proposes to introduce the subject again on the present occasion by a description of two arrangements for superheating steam: the one by Messrs. Parson and Pilgrim of London; and the other by Mr. David Patridge of H. M. Dockyard, Woolwich: giving in each case the practical results of the employment of superheated steam.

Figs. 1 and 2, Plate 3, represent a longitudinal section and front elevation of Messrs. Parson and Pilgrim's arrangement of superheating apparatus as applied to marine engine boilers. In the furnaces AA are placed semicircular superheating pipes B, the number of which is dependent upon the temperature required. A pipe C from the steam chest conveys the common steam to the pipes B, in which it is superheated and then passes through the pipes DD to the engines. A trial of this apparatus as shown in the drawings was made about two years ago with a 10 horse power boiler connected with an engine having a break applied, in order to ascertain the possibility of regulating the extent of superheating and of using superheated steam direct in the

cylinders of steam engines. A number of experiments were tried for a period of nine months, both with common and superheated steam, and the following results were obtained: by using superheated steam one third less water and one third less fuel were consumed, and in many cases one arched pipe gave a sufficient amount of superheating surface to realise the benefit of the plan to that extent of economy. This apparatus was applied about a year ago to a stationary boiler in the Royal Arsenal at Woolwich, and was tested for 64 days, when the result arrived at was that a saving of 30 per cent. was effected by its use.

Much opposition was however experienced to the employment of superheated steam, and consequently a full investigation of the chemical question involved was made by Professor Taylors and Brande, as to the effects of using superheated steam and the alleged danger from explosion attending its employment; experiments were made with a steam boiler that was working with this superheating apparatus, and the following results and conclusions were arrived at by them. The steam was issuing from the boiler at a pressure of 20 lbs. per inch, equivalent to a temperature of about 264° Fahr.; and after traversing the iron superheating pipes heated to redness at the back of the furnace, its temperature in passing into the steam chest was found to vary from 484° to 540°, the pressure remaining unchanged. As the steam escaped from a jet, and before it had assumed a state of visibly condensed vapour, it immediately extinguished the flame of burning paper. The superheated steam was then received and condensed in a vessel of water under such circumstances as to allow of the collection of any gases which might be mixed with it. Two portions of gas were thus collected and carefully examined: the result was that no hydrogen was present, nor any inflammable gas or mixture of gases. The incondensible gas which was then collected from the condensed vapour was found to extinguish the flame of a candle; and was apparently nothing more than nitrogen derived from air contained in the water and liberated by heat. The oxygen of this air is fixed by the iron of the red-hot pipe, while the nitrogen constituting from 2-3rds to 3-4ths of the air is set free and escapes with the superheated steam. Although steam passed over pure metallic iron heated

to redness (1000°) is so decomposed that the oxygen is fixed by the iron while hydrogen gas is liberated, this chemical action is of a very limited kind, and in order to obtain any considerable quantity of hydrogen a very extended surface of iron is necessary, as in the form of thin plates or iron turnings; for the surface of the iron is rapidly covered with a fixed and impermeable layer of the magnetic oxide of iron, and thenceforth the chemical action is completely arrested. If the interior of an iron pipe has been already oxidised by passing through it while in a heated state a current of air, there will be no decomposition of the steam during its passage through it: if the interior of an iron pipe were not thus previously oxidised, it would speedily become so by the oxygen derived from the air which is always mixed with the steam. Hence, chemically speaking, under no circumstances would any danger attend the process of superheating steam, as conducted with this apparatus. Hydrogen gas alone is not explosive, but simply combustible; and assuming that it was liberated as a result of the decomposition of superheated steam, its property of combustibility would not be manifested in the midst of the enormous quantity of aqueous vapour liberated with it and condensed round it. There could be no explosion, inasmuch as hydrogen, unless previously mixed with oxygen, does not explode; and oxygen is not liberated but actually fixed by this process. The vapour and gas evolved under the form of superheated steam tend to extinguish flame and to prevent combustion from any other cause.

This superheating apparatus was then applied to the Osprey, one of the boats on the Thames of the Waterman's Steam Packet Company, and the following results were obtained and confirmed by the company's engineer as to its working during two months' trial in the early part of last year. The saving in fuel effected by the use of the apparatus was 33 per cent., whilst the gain in revolutions of the engines was 11 per cent. with a decrease of pressure on the boiler. The cylinders remained as bright and in as good order as possible, although the temperature of the steam used was upwards of 440°; and the trunnion packing lasted the whole time. An objection was however raised on the part of the Board of Trade to these experiments in the Osprey with super-

heated steam being continued whilst carrying passengers, on account of the supposed danger involved. But the result of an investigation made by Professor Faraday for the Board of Trade was that the apparatus was entirely safe; and that as respected the decomposition of the steam by the heated iron of the tubes, and the separation of hydrogen, no new danger was incurred. Under extreme circumstances the hydrogen which could be evolved would be very small in quantity: would not exert greater expansive force than the steam: would not with steam form an explosive mixture: would not be able to burn with explosion; and probably not at all, if it, with the steam, escaped through an aperture into the air or even into the fireplace. Supposing the tubes were frequently heated overmuch, a slow oxidation of the iron might continue to go on within; this would be accompanied by a more rapid oxidation of the exterior iron surface, and the two causes would combine to the gradual injury of the tubes. But that would be an effect coming under the cognizance of the engineer, and would require repair in the ordinary way, and he did not consider even this action likely to occur in any serious degree; he examined a tube which had been used many months, which did not show this effect: and no harm or danger could happen to the public from such a cause.

This superheating apparatus was consequently applied to another of the boats of the same company, the Swift; and the result stated as to its working up to the present time is a saving in consumption of fuel of between 30 and 40 per cent.: the apparatus is consequently being applied to all the remaining boats of the company, 11 in number. A trial of this superheating apparatus has also been made in H. M. steam tug Bustler; and the mean result of 37 trials, with a pressure of $8\frac{1}{2}$ lbs. and a temperature of 380° in the cylinders, was a saving of fuel of 25 per cent. with the use of superheated steam.

Figs. 3 and 4, Plate 4, represent the arrangement of superheating apparatus of Mr. Patridge of H. M. Dockyard, Woolwich, as applied to marine boilers. It consists of a cylinder A filled with tubes, placed vertically over the uptake and resting on the steam chest at the base of the chimney; the hot air and gases from the furnaces pass up through the tubes and through the annular space B round the

cylinder, and the steam from the boiler enters the cylinder by the pipes CC, and passes thence to the engines by the pipes DD, being deflected in its passage around the tubes by the vertical plates E: a thermometer F is inserted in a cup of mercury in one of the pipes D. This apparatus was applied to H. M. steam ship Dee of 200 horse power, and experiments were carried on over a period of many months under the superintendence of Mr. Dinnen and other gentlemen connected with the Admiralty; and the result obtained was an economy of fuel equal to from 20 to 25 per cent. Several vessels have now been fitted with this superheating apparatus, including the Royal Mail steam ship Tyne of 400 horse power, the Cunard Company's steam ship Persia of 1000 horse power, and the screw engines of the Great Eastern. Now taking only the vessels already supplied with this superheating apparatus, amounting to about 5000 horse power, and assuming that they actually steam four months out of the year with a consumption under ordinary circumstances of 8 lbs. of coal per nominal horse power per hour, the saving if superheated steam be used would amount to upwards of 10,000 tons of coal per annum; and the writer understands that such is the enormous consumption by four of our large steam ship companies, that if superheated steam were used by all their ships the saving would exceed £2000 per day throughout the year. This superheating apparatus works at a temperature ranging from 360° to 390°, and it is considered that the superheating tubes will wear out at least two sets of boilers.

It is evident that in any arrangement the proportion of superheating surface required will depend entirely upon where the apparatus is placed and the temperature intended to be worked at. For a temperature up to 450° this surface is found to vary from $\frac{1}{2}$ square foot to 5 or 6 square feet per nominal horse power: in Mr. Pilgrim's apparatus about 0·50 to 0·55 square foot is sufficient for each nominal horse power at a temperature of 400°.

It thus appears that superheated steam may be safely used with an economy of fuel alone varying from 20 to 35 per cent.; and at the same time the feed and injection are both relatively diminished; the load upon the air pump is diminished, and the number of

revolutions of the engine increased in proportion. If attention is now turned to the causes of this great economy—bearing in mind that by the application of heat water assumes the form of steam under varying conditions, and that vessels filled with steam, free from water, may be heated to any degree without greater danger than in heating common air—there are found to be three causes at least. The first arises from the circumstance that each globule of steam carries with it a portion of water as it ascends, and this occurs whether the generating vessel be open to the atmosphere or closed under any pressure. There is also the tendency of the surface water, more or less, to combine and pass over with the steam in variable quantities in the form of minute unevaporated particles of water, which is a constant occurrence, probably arising from cohesive affinity. The first effect therefore of additional heat imparted to the wet steam is to set at liberty those portions of water held in suspension, and a consequent increase in the volume of steam takes place. Superheating then commences, the temperature of the steam becoming increased beyond that due to the pressure under which it was generated, and the volume of steam is further increased in proportion to the additional heat supplied. The third effect is that by means of the increased temperature of the steam (as was clearly explained in the former paper referred to on this subject) the cylinder is prevented from becoming a partial condenser. These three causes combined produce the great economy resulting from the application of superheated steam.

In reference to the condensation of the superheated steam, it has been found by the writer that the water evaporated, the fuel consumed, and the injection water required, bear about the same ratio as when the steam is not superheated, the injection water being reduced in the same proportion as the feed water and the fuel. Hence it follows that no more heat has absolutely been imparted to the steam than it previously contained, however high its temperature be raised; the effect of the superheating appearing to be merely to increase the sensible and diminish the latent heat, their sum still remaining a constant quantity.

Another advantage of superheated steam is that the principal moving parts of the engine are less liable to accident; for with

ordinary saturated steam the engine is literally (as described in the former paper) a mixed steam and water engine, and by the deposition of water the cylinders, pistons, and rods are exposed to constant danger, which unfortunately is too often realised. Whilst a large steam ship is at full speed and before any precaution can be taken, the mischief is too often done; a piston is broken and perhaps covers and rods also, and the engines are stopped at a time when the consequences may be very serious. This is not an exceptional case, but one of too common occurrence both at home and abroad; a sudden change in the atmospheric pressure, alteration of the ship's course, or a transition from bad fuel to good, and many other circumstances cause a more rapid and sometimes instantaneous generation of steam, which carries more water with it into the cylinders than can be got rid of in time to prevent accident. These cases generally occur when the fires are forced and it is difficult to get steam; the draught through the furnaces becoming suddenly influenced by one or other of the above changes. By the adoption of superheating therefore, apart from the consideration that much of this water would be evaporated in its passage through the superheating apparatus, only 2-3rds of the fuel is now required that was before consumed in the same time, and consequently the necessity for hard firing will cease and one great cause of priming be removed. The steam generated is itself simply ordinary steam; for it is found difficult to superheat it in the same vessel in which it is generated, unless that vessel be wholly in contact with the fire, and the issuing orifice be far removed from the generating surface.

The economy of superheating applies not only to the engines of the navy and mercantile marine of this country; but it is important that every owner or employer of steam power throughout the country, every manufacturer who uses heated cylinders, rollers, baths, and high temperatures in any operations either chemical or mechanical, should earnestly co-operate in this subject by testing the application of superheated steam for their own particular processes. In conclusion the writer would urge this important subject on the attention of all, with the further consideration of the circumstance that to coal and iron this country greatly owes its present leading position with

reference to surrounding nations, in commerce, wealth, and power; and that any means of economising coal is a means of directly adding to and prolonging the supply of that important material.

Mr. E. A. Cowper observed that it was desirable to have full information as to the actual consumption of fuel and water before and after the superheating apparatus was applied, and as to the construction of the boilers employed, since the results depended greatly on whether the boilers were economical in fuel or of defective construction.

Mr. W. B. Johnson had seen a trial of superheated steam some time ago at Messrs. Hoyle's print works in Manchester; but no material economy of fuel was produced, and a great objection was felt to tne superheating on account of its destructive influence on the cylinders and packing, and it was finally abandoned on that account, though the superheating apparatus had been put in at a considerable expense. The boilers were working with 50 lbs. steam, and were cylindrical with internal flues and of a tolerably economical construction, ample in power and steam room; they were driving a pair of engines with 20 inch cylinders and 3 feet stroke; the steam was superheated by an additional boiler round which the residue of heat from the principal boilers was conveyed.

Mr. C. Markham observed that in any trials of superheating apparatus in connexion with boilers, it was necessary to know the temperature in the chimney; and he believed the greatest portion of the advantage would be found to arise in many cases from the improvement of defective boilers which were previously wasting fuel, the superheating apparatus affording an additional area of heating surface which would increase the evaporative duty of the boiler. In steam boats particularly a great heat escaped from the chimneys, showing the boilers to be very imperfect in absorbing the heat from the fuel consumed; and this loss would undoubtedly be diminished by the simple increase of heating surface given by the addition of the superheating apparatus. In the locomotives on the Midland Railway of modern construction the actual evaporation of water was found to

be generally 7 lbs. per lb. of fuel; and with that evaporation the heat was frequently so entirely absorbed by the boiler, that a considerable proportion of the exhaust steam was condensed and fell back from the top of the chimney; and it was only with heavy loads that there was sufficient heat drawn through into the chimney to carry the steam away to any distance. In these cases he believed the application of the superheating apparatus would not give any advantage, nor in any other instance where it was applied to properly proportioned boilers.

Mr. J. Robinson remarked that the chimneys of some locomotives had formerly been made with a water chamber surrounding them, with the view of saving part of the waste heat; but it was not found to be worth the addition. He doubted whether a superheating apparatus would cause any material saving of fuel, if the boilers were good and of economical construction, and thought there was then but little further economy of fuel to be obtained; there would however be a decided advantage in getting the steam dry and preventing condensation in the cylinder. In ordinary marine boilers there was certainly a serious waste of fuel at present, from the great loss of heat in the uptake flue.

Mr. F. J. Bramwell thought there was an important circumstance to be considered which distinctly showed the economy attendant upon superheating to be due to the principle of superheating: that the same total power was then obtained from a smaller quantity of water evaporated as well as of fuel consumed; for it appeared from the results of the trials that the water was reduced in a similar proportion to the fuel. This set aside the explanation of the saving being effected by waste heat previously lost being absorbed by the superheating apparatus; and the economy that had been obtained could not therefore be attributed to improved application of the fuel in the boiler, but must be referred to some other cause arising from the action of the superheated steam.

Mr. C. W. Siemens had seen the trial of superheated steam that had been referred to at Messrs. Hoyle's works; and though the result had not proved favourable in that case, he thought that the failure might be fully accounted for by the imperfect way in which

the experiment had been tried: any single cases however of want of success could not be admitted, he considered, as permanent objections to the introduction of a system. There was much difficulty in making an experiment complete and arriving at the correct result, and the value of the result depended upon the mode in which it had been conducted and a perfect knowledge of all the circumstances involved. Amongst the circumstances to be considered in any experiments on superheated steam were the actual size and construction of the engine, whether the cylinders had steam jackets or were well or imperfectly clothed, the degree of exposure and length of the steam pipes, and the construction, form, and size of the boilers: the particulars of all these circumstances should be carefully noted in any experiments to determine the practical value of superheating the steam.

The advantages to be attained by superheating, most of which were referred to in the paper, were—firstly, entirely preventing the passage of priming water with the steam, by completely evaporating this water in passing the steam through the superheating apparatus; secondly, obtaining a greater bulk of steam from the same water, by its expansion with the increase of temperature; and thirdly, preventing any condensation of the steam by contact with the cooler sides of the cylinder, whereby the steam could be kept in a perfectly dry state throughout the entire stroke. The evaporation of the priming water was a clear gain, as it was difficult if not impossible to prevent priming altogether, and in many cases the amount of priming was very considerable, causing serious risk of injury to the engine as well as waste of heat. In regard to the advantage to be obtained by adding heat to the steam to increase its bulk, this involved the theoretical question of the rate of expansion of steam by heat. It had been generally assumed that isolated steam expanded under all circumstances at the same rate as air, namely 1-490th of its bulk at 32° for each degree Fahr.: but he had shown by the results of experiments given in a paper at a former meeting (Proceedings Inst. M.E. 1852, page 131) that its rate of expansion was considerably greater when near the condensing or boiling point, being in the case of atmospheric steam an average of 5 times

the rate of air up to 230° and 3 times up to 260°; diminishing in fact in a ratio that could be represented by a hyperbolic curve, approaching gradually at higher temperatures to the same uniform rate of expansion as air which would be represented by the asymptote to the curve. On this assumption it followed that there would be a certain advantage gained in applying heat direct to expand the bulk of steam, instead of employing the same heat to generate an additional quantity of ordinary steam; but the extent of gain that could be attained was not large, since the rise of temperature was practically limited to a moderate range, and the specific heat of steam near the point of saturation was proportionately great.

The most important source of economy in superheating steam was no doubt to be found in preventing condensation in the cylinder; for the consequence of condensation of any portion of the steam on entering the cylinder was the total loss of the power of that steam during the remainder of the stroke. But in order to effect this object completely he considered that it was not enough to supply extra heat sufficient to heat the metal of the cylinder up to the temperature of saturated steam of the maximum pressure, whether by superheating the steam or by a steam jacket round the cylinder; for although this were done, there must still be condensation in the cylinder during the expansion of the steam, on account of the loss of heat accompanying the development of moving power from the pressure of the steam on the piston; since there would be as much heat lost from the steam (or so to speak rendered latent in the form of power) as was equivalent to the total work done by the steam, according to the accepted theory of the mutual convertibility of heat and power, by which according to Joule's results one unit of heat (the quantity of heat required to raise the temperature of 1 lb. of water 1° Fahr.) was equivalent to or became converted into a power of 770 ft.-lbs. (770 lbs. lifted 1 foot). This amount of heat lost during the expansion of the steam must consequently be supplied by superheating the steam originally admitted to the cylinder in order entirely to prevent condensation; and this appeared about the point to which superheating could be carried advantageously, and generally speaking required an addition of about 100° to the natural tempera-

ture of the steam, varying of course with the degree to which the steam was worked expansively. The circumstance that this amount of heat was got rid of during the expansion of the steam in the cylinder went far to account for the statement given in the paper, that the quantity of injection water required to condense the steam was found to be proportionate to the total weight of steam, or of water evaporated, whether the steam were superheated or not: for the heat added to the steam by superheating had probably been hardly sufficient to replace the loss arising from expansion and from the cooling by conduction and radiation from the metal of the cylinder. He believed that by superheating the steam judiciously a saving of from 15 to even 20 per cent. of fuel might be effected, even upon a properly constructed engine; but he was equally satisfied that superheated steam must eventually give way to regenerated steam, by which alone the full equivalent of motive power could be obtained from heat, diminished only by the unavoidable losses from radiation, &c.

In the use of high temperatures there was much difficulty in getting the joints to stand steam-tight, which he had experienced in superheating steam in his regenerative steam engine; and after the failure of various cements and copper rings, he had succeeded in making a joint that stood even a red heat and remained quite steam-tight. The cement he used was composed of red lead and oil mixed with as much dust of cast iron as could be worked into it. He showed a specimen of the joint fresh made, and one that had been exposed to a red heat in which the cement had become nearly as hard as iron itself.

Mr. H. Maudslay thought there was no doubt that the application of superheated steam was generally but little understood, and it was highly desirable for every information to be obtained upon the subject, with full particulars of the different trials that had been made; these would serve to prevent the repetition of many failures, by the circumstances under which the failures had occurred being known. It was requisite for all particulars to be given of the condition of th boilers and engines both before and after the experiment in each case, and of the manner in which the experiment was conducted, whether in the ordinary course of regular work or otherwise; for with special

care in casing up all the parts and with the use of picked coal great differences in result might be obtained without any change in the apparatus employed.

Mr. W. B. Johnson did not see how the reduction of injection water that had taken place with the superheating apparatus could be connected with the prevention of priming water passing over from the boiler.

Mr. F. J. Bramwell observed that the effect of superheating in preventing loss of water by priming would be to diminish at the same time the proportionate supply of injection water, since the water previously passing away uselessly from the boiler as priming would then be evaporated and used as steam, and so much less feed water would have to be supplied in order to maintain the same supply of steam; the same quantity of injection water would be required for condensing the steam as before, but there would be no hot priming water mixed with the steam requiring a further supply of injection water to cool it down. Thus supposing that 1-4th of the water from the boiler had previously been wasted by priming, and it required 1-8th as much injection water to cool down a portion of priming water as to condense the same quantity of water from the state of steam; then, 1-4th of the water coming over in the liquid state, 1-32nd of the whole injection water would be spent in cooling it down, and this proportion of injection would be saved when the whole of the priming water was evaporated into steam by superheating: but then 1-4th of the feed water would be saved to produce the same supply of steam, whilst only 1-32nd of the injection would be saved.

Mr. E. A. Cooper showed a series of indicator diagrams taken from an engine without a steam jacket, with the theoretical expansion curve drawn upwards from the extremity of the actual curve to the top of the figure; and showed by the space left between the curves the proportion of loss of power caused by condensation in the cylinder during the early part of the stroke, forming a deposit of water in the cylinder, a portion of which was evaporated again towards the end of the stroke owing to the cylinder metal being then hotter than the expanded steam. The whole of this power might be saved if condensation were prevented, as was shown by a corresponding indicator

diagram from a cylinder having a steam jacket separately supplied with hot steam direct from the boiler, in which there was no difference of area between the theoretical and the actual expansion curves; the latter being only slightly below the theoretical curve in the early part of the stroke, and a little above it at the end, in consequence of the slight superheating effect of the hotter steam jacket.

Mr. J. WETHERED (of the United States) said that in the earlier attempts at applying superheated steam the greatest difficulty experienced was from liability of getting the steam sometimes overheated, causing damage to the pistons and slides of the engines; and since he had been in this country he had seen two steamers lying in the Victoria Docks that were now having the cylinders rebored in consequence of their being so badly cut from this cause. He had been experimenting on the subject for several years; and finding this great objection in the use of superheated steam that it was liable to injure the cylinders and slides, the idea had then occurred to him that, since superheated steam was too dry and ordinary steam too wet, a mixture of the two might be employed, so as to afford the means at all times of completely controlling the temperature of the steam working in the engine, by varying the proportion of the mixture as might be required by the varying temperature of the superheated steam. He had now tried this plan extensively and found it thoroughly satisfactory, and considered it was a great advantage to have this means of instantly controlling the temperature of the steam; for the temperature of the superheated steam fluctuated with the heat of the furnaces, and there was sometimes a variation in the temperature of the uptake flue of 200° or more in the course of a few hours, so that the temperature of the steam passing to the cylinders was entirely beyond the control of the engineer. By his system of having two steam pipes from the boiler, one supplying the cylinders with plain steam and the other with superheated steam, the supply was easily regulated to the temperature necessary to develop the maximum power with the most perfect lubrication, and a nearly uniform temperature was maintained as indicated by a thermometer fitted in the steam chest; and in case of the slides beginning to seize, this could be stopped at once by turning on more of the ordinary steam.

He had found the economy arising from the use of mixed steam to be fully as great as had been stated, and with the best application he was satisfied that an economy of more than 40 per cent. would be obtained. The plan of mixed steam had been tried for two years in H. M. steamer Dee, and the average result obtained was an economy of 32 per cent.; the consumption of coal averaged 3·95 lbs. per indicated horse power per hour, and the previous consumption was 5·8 lbs.; the Admiralty yacht Black Eagle altered to the superheating plan had a consumption of 6·5 lbs. per indicated horse power per hour on the trial trip previous to the alteration, and about 6 lbs. might probably be taken as the general consumption of steamers in this country. In the steamer Dee the boilers were old multitubular boilers in good condition, and the engines were old side-lever engines. A trial of mixed steam was also being made in the Avon steamer, which had made one voyage between Rio and Southampton using ordinary and mixed steam on alternate days, and all the machinery had continued in perfect order; while in the tropics the slides had only once been found screaming for want of oil, but by turning on more of the ordinary steam the noise was immediately stopped. The economy effected in this case had been stated at 15 per cent.; but he considered it might be taken at 30 per cent., if mixed steam were used continuously and the gain in speed of the vessel included. The Rhadamanthus was now being fitted up with superheating apparatus, and was intended to be tried carefully for a certain time with all the steam superheated, and then similarly with mixed steam. In all the trials made by the American, French, and British governments, mixed steam had proved far more economical than either plain or superheated steam: the economy of 33 per cent. could be readily accounted for, as he found by experience that the supply of feed water to the boiler required to be reduced one third.

Mr. T. Pilgrim said that the full saving of fuel named in the paper had been obtained by the use of the superheating apparatus, the mode of working and quality of fuel being exactly the same in both cases, and no other alteration made in the boilers than the addition of the superheating apparatus: in the boats on the Thames that had been referred to the regular consumption of coal previously was 22 sacks of

2 cwts. each per day; but with superheating it was only 13 sacks, or 41 per cent. reduction whilst doing the same work and working for the same length of time. In regard to the durability of the superheating apparatus, the iron arch pipes had been working constantly for 18 months in a stationary boiler in London and showed no sign of failure yet; they were wrought iron pipes $\frac{1}{2}$ inch thick and $3\frac{1}{2}$ inches diameter inside; and those in boats running on the Thames which had been 8 months in wear were of a similar make.

The cylinders and valve faces were not scored in the least and had an excellent smooth surface, and he thought this was due to the circumstance that no priming water ever went over into the cylinder, and consequently no dirt was carried into the cylinder; for he believed the cutting of cylinders was due to the dirt carried over by the priming water, and that they were not liable to injury if kept quite clean, although very hot. No difficulty had been found in lubricating the cylinder; ordinary tallow was used, and there was not any greater quantity required than usual. The temperature regularly employed was about 410° in the superheating apparatus, which became reduced to 385° in the valve chest before entering the cylinder, although the steam pipes were well coated.

The Chairman asked whether he considered that the quantity of condensing water and of feed water continued in the same proportion with the superheating as without it.

Mr. T. Pilgrim replied that it had been found to be nearly so, as far as they had the means of ascertaining the proportionate quantities; this was done by measuring the area of opening of the injection and feed cocks, which had rectangular openings with the position of the opening accurately marked, and graduated handles showing the extent of opening. The area of opening for the feed was reduced one fourth when the superheating apparatus was used, whilst the area for the injection was reduced one third.

Mr. F. J. Bramwell remarked that if those figures were correct, the injection diminished in that case rather more in proportion than the feed.

Mr. W. B. Johnson thought the relative quantity of water could not be measured with sufficient accuracy by the area of passage

through the opening of the cock, and it was very desirable to have the experiment tried with more accurate measurement. In reference to the application of superheating he thought that in any experiments it was the best course to get an economical boiler first before trying the experiments to ascertain the results of superheating: in a case that he had known of a steamer at Liverpool the supply of steam could not be kept up by the boilers, although vigorously fired; the steam room was much too small, and consequently water was continually carried off by priming, and had to be replaced by cold water; the difficulty was completely removed by adding a large steam dome to give more steam room and thus prevent priming, and the boilers then worked easily. In this instance superheating the steam so charged with water would be attended with considerable economy, and yet the economy would not be due to superheating entirely but principally to perfecting an imperfect part of the boilers.

Mr. J. Wethered said that in the experiments with the Dee the supply of water was measured by the opening of the feed cock which was graduated with accuracy; and he had made a trial by supplying a boiler from a measured tank, with the same result.

The Chairman proposed a vote of thanks to Mr. Ryder for his paper, which was passed.

The following paper was then read:—

ON GIFFARD'S INJECTOR FOR FEEDING STEAM BOILERS.

By Mr. JOHN ROBINSON, of Manchester.

The object of the Water Injector forming the subject of the present paper, called by the inventor M. Giffard of Paris the "automatic injector," is to feed steam boilers by a self-acting apparatus, employing the direct application of the steam from the boiler without the intervention of machinery, and ready for action at all times independent of the working of the engine, and free from the liability to derangement and the wear and tear incidental to machinery in motion. This injector has attracted special attention, both from the importance of the object aimed at and the success with which this object has been attained, as well as from the novelty and singular nature of its action and the great simplicity of its arrangement; it has proved so completely successful in practical working that its use is now rapidly extending for various classes of boilers.

The construction of the injector is shown by the specimen exhibited and by the accompanying drawings, Plates 5, 6, and 7. Fig. 1, Plate 5, is a vertical section of an injector of the dimensions usually fixed upon locomotives, and Figs. 2 and 3 are transverse sections; Fig. 4, Plate 6, is an enlarged vertical section of the conical steam and water passages. Figs. 11 and 12, Plate 7, show the application of the injector to stationary or marine boilers and locomotives.

The steam from the boiler is admitted through the pipe A furnished with a cock B, and passes down through the perforated cylinder or tube C, which is made conical at the bottom, the area of the aperture being regulated by the conical rod D adjusted by the screw and handle E. The jet of steam issuing from the orifice of the tube C encounters the feed water in the chamber F, which enters from

the feed pipe G; the supply of feed water is regulated by raising or lowering the tube C by means of the handle H and screw of quick pitch. The stream of feed water propelled by the steam jet issues from the upper orifice I, and passes into the mouth of the lower pipe K leading into the boiler, the intervening space L being open to the atmosphere, so that the stream of water can be seen through the sight holes M at this part of its passage while the injector is at work. A check valve is inserted at N, to prevent the return of the water from the boiler when the injector is not working. The overflow pipe O carries off any overflow occasioned in starting the injector to work, and the sight holes M are covered by a circular slide.

In starting the injector to work, the handle H is first turned into the position suited to the pressure of steam in the boiler; this permits the access of water to the instrument and regulates its admission. The steam cock B is then opened, and the handle E turned slightly so as to elevate the screwed rod D, which admits a small quantity of steam to the conical opening I. A partial vacuum is thus produced in the chamber F by the rush of steam through the opening I, and the water flows into it. As soon as this happens, which can be observed at the overflow O, the screwed rod D is gradually raised until the overflow ceases, thus giving full liberty to the steam to act upon the water at I and drive it into the boiler through the pipe K and the valve N.

The supposed relative movements of the steam and water when the injector is in perfect action are shown in Figs. 1 and 4, Plates 5 and 6. Fig. 5, Plate 6, shows the result of an excess of steam, and Fig. 6 of an excess of water. In case of an excess of steam, Fig. 5, the opening I is entirely filled by it and the water forced back through the pipe G, the steam escaping through the overflow O. In case of an excess of water, Fig. 6, the quantity of steam rushing from the orifice of the tube C is so small in proportion as not to permit of its reaching the orifice I before it becomes entirely condensed; its velocity is thus lost, and there is not power enough left to overcome the resistance of the pressure in the boiler, and the water escapes at the overflow O.

The injector has now been in use upwards of nine months in France, a large number having been put to work there, of which a considerable proportion have been applied to locomotive engines; and these have been found so thoroughly satisfactory that their application to locomotives, as well as to marine, stationary, and agricultural boilers, is being widely extended: they are especially advantageous for boilers in motion and when the engines work at high velocities, on account of the certainty of their action together with their great simplicity of construction and freedom from risk of derangement. Injectors have been working for six months in England, the first having been procured from France by the writer's partner, Mr. Stewart, and tried upon a stationary boiler at their works. It was subsequently put to work upon a ballast engine upon the St. Helen's Railway, where in the course of a few days the driver was able to dispense with the use of the engine pumps, and to maintain the level of the water in the boiler by the injector alone. A larger injector was then tried upon a goods engine on the same railway, which proved entirely successful: and the writer, with the kind co-operation of Mr. Cross, the engineer of the railway, made experiments with this and another injector of the same size manufactured at Manchester, to ascertain what effect the temperature of the feed water, the vibrations and concussions caused by the action of the break, passing over crossing points or shunting wagons, would have upon the regularity of the water passing through the instrument. The general result ascertained by these experiments was that the injector would work at all steam pressures up to the maximum working pressure of the boiler, 110 lbs. per square inch; and would draw water from the tender of any temperature up to 110° Fahr.; and that neither the sudden application of the break, nor any shock produced in passing bad points or in shunting, interfered in any way with its efficient working. The only difficulty which arose was when the water in the tender had become hot and at the same time very low in level, under which circumstances conjoined the degree of vacuum capable of being produced in the water chamber of the injector was not sufficient to lift the water to the height at which it was placed, 29 inches above the footplate; this inconvenience however was readily obviated by lowering the

injector so as to bring the water entrance within a few inches of the level of the bottom of the tender. In using the injector no difficulty was experienced in so regulating the openings for steam and water as to produce a constant and regular supply of any required quantity of water to the boiler without waste from the overflow pipe. The result of the continued working of these injectors on the St. Helen's Railway was so satisfactory that ten of them have been ordered for the engines on this railway: and it has been decided to replace all the pumps of the locomotives on a foreign railway by injectors, after careful trial of one of them; and one injector only is to be placed on each of eight locomotives now being built for the same railway at the writer's works, the pumps being dispensed with altogether.

It may be desirable here to mention some collateral advantages arising from the use of the injector on locomotive engines. The space hitherto occupied by the pumps is saved, and becomes available for other purposes: the power of the engine required to work the pumps is economised, and the wear and tear of the parts through which this power is transmitted is entirely avoided: and the water level can be maintained at any desired height whether the engine is moving or not; also the steam often blown off when standing can be used for the purpose of forcing water into the boiler.

Several sizes of injectors are made to suit different purposes: that generally adopted for locomotives, as shown in Fig. 1, Plate 5, measures 8 millimetres or 0·32 inch in the smallest diameter of the throat K. This diameter is taken as the standard point of measure for the power of the instrument, and the designation of the dimensions of the French injectors in millimetres has been adhered to by the writer, from the convenience of the decimal system of measurement. The size of 8 millimetres throat is called No. 8 injector; another size No. 6 of 6 millimetres throat being made for stationary boilers of ordinary size and pressure, and corresponding smaller ones No. 4 and No. 2 for smaller boilers and for agricultural and portable engines: a larger size No. 10 of 10 millimetres throat is designed for large locomotive and other boilers of great evaporating power. In the case of a goods engine drawing a load of 24 wagons up a gradient of 1 in 96 about 2 miles long on the East Lancashire Railway,

Mr. Lees has found that all the water given off by evaporation during the ascent could be easily replaced by a No. 8 injector, without reducing the steam pressure 1 lb.; the initial pressure of 100 lbs. having been maintained during the whole time, and rising immediately the summit was attained.

For the purpose of ascertaining the limits of the circumstances under which the injector can be worked, a series of experiments have been made by the writer with instruments of different sizes fixed to stationary boilers working at 60 lbs. pressure; one of which being connected with an adjoining boiler in which the pressure could be reduced to any desired amount gave great facility for measuring the power of the injector when feeding by lower into higher pressures: the relative pressures being accurately observed by Schaeffer's and mercurial steam gauges. The temperature of the feed water also could be varied at pleasure, by introducing into it either hot or cold water as required. The general results obtained from these experiments were, that water could be forced into a boiler by the injector when the steam pressure was not below 5 lbs. per square inch; that the temperature of the feed water might be raised up to 148° Fahr., requiring to be varied in the inverse proportion to the pressure of steam; and that surplus power was developed by the instrument, available for forcing water into a boiler at a higher pressure than the one from which the steam was obtained, the injector having been effective with steam of 24½ lbs. pressure above the atmosphere in forcing water into a boiler at 48½ lbs. pressure. The particulars of these experiments are given in the following tables: in all cases the surface of the water in the supply tank was at least 2 feet below the level of the water chamber of the injector, the vacuum in that chamber being from 1 lb. to 1½ lbs. below the atmosphere during the operation.

Table I shows approximately the maximum temperature of feed water hitherto capable of being used at various pressures of steam :—

TABLE I.

Maximum Temperature of Feed admissible at different Pressures of Steam.

Pressure of Steam, lbs. per square inch	10	20	30	40	50	100
Temperature of Feed, Fahrenheit.....	148°	138°	130°	124°	120°	110°

These circumstances in the action of the injector render its application to the supply of marine boilers particularly advantageous, since the low pressure at which they usually work, and the fact that the feed water has not to be drawn up from a lower level, enable a high temperature to be imparted to the water without endangering the regularity of the feed; besides which the simplicity and certainty of action of the injector obviates the inconvenience and danger arising from the failure of the donkey and other pumps now usually employed for feeding these boilers. It will readily be seen that the instrument has all the advantages sought in the use of donkey pumps, by its ability to feed the boilers quite independently of the movement of the engines; and also that it utilises all the steam which it draws from the boiler, in raising the temperature of the water while passing through the injector itself.

Table II shows the quantity of water in gallons per hour which a No. 4 injector is capable of delivering at various steam pressures, the temperature of the feed water being 95° Fahr. :—

TABLE II.

Quantity of Water Delivered at different Pressures of Steam.

Pressure of Steam, lbs. per square inch	5	10	20	30	40	50	60
Water Delivered, gallons per hour.....	93	124	150	186	210	244	259

As an addition to this experiment it may be stated that with a No. 8 injector working at a pressure of 150 lbs. per square inch as much water was passed through the throat of 8 millimetres or 0·32 inch diameter as was supplied to the tank by a pipe of $1\frac{1}{2}$ inch bore from a cistern at least 20 feet higher than the tank.

Table III shows the quantity of water in gallons per hour delivered by a No. 8 injector according to the temperature of the feed water employed, the steam pressure being constant at 60 lbs. per square inch :—

TABLE III.

Quantity of Water Delivered at different Temperatures of Feed.

Temperature of Feed, Fahrenheit.........	60°	90°	105°	120°	130°
Water Delivered, gallons per hour.........	972	786	698	486	382

Table IV supplies a measure of the power of the instrument by showing the excess of pressure which may exist in the boiler fed by the injector above that of the steam used for working the injector :—

TABLE IV.

Low Pressure boiler supplying High Pressure boiler: Maximum Difference of Pressure admissible.

Temperature of Feed.	Pressure of Steam. Low Pressure.	High Pressure.	Difference of Pressure.	Result.
	Lbs.	Lbs.	Lbs.	
74°	50	59	9	
	40	55½	15½	Slight overflow.
	38	56½	18½	Overflow increased.
86°	36	57	21	Delivery almost ceased.
74°	50	51½	1½	
	37	49	12	Slight overflow.
	33	50½	17½	Overflow increased.
96°	30	52½	22½	Delivery almost ceased.
74°	45	47	2	
	34	45½	11½	Slight overflow.
	31	45½	14½	Overflow increased.
106°	24	48½	24½	Delivery ceased.

The following is an approximate rule used by the inventor, derived solely from experiments in France, for calculating the quantity of water which can be delivered for non-condensing engines by an injector having a given diameter of throat:—

$$Q = 6{\cdot}16\, d^2 \sqrt{p}$$

Q being the quantity of water delivered in gallons per hour, d the diameter of throat in millimetres, and p the pressure of steam in atmospheres. The size of injector for a given nominal horse power of boiler is ascertained from the converse rule:—

$$d = \sqrt{\left(\frac{Q}{6{\cdot}16\, \sqrt{p}}\right)}$$

The above experiments are given only as approximations for general guidance, since they are not considered by the writer sufficiently accurate for the purposes of exact calculation as to the action of the injector.

It may not be out of place now to suggest a theory according to which the injector is supposed to act. The pressure on all parts of the interior of steam boilers being equal, some reason must be sought why steam taken from one part is able to overcome the resistance opposed to its entrance into another part of the same boiler. Looking at the construction of the instrument itself, it is evident that when it is in operation, and the valve N, Fig. 1, open or removed, the pressure in the boiler acting through the pipe K appears free to resist the entrance of the water into it. It may be assumed that steam or water escaping from a boiler into the atmosphere does so at a velocity proportioned to its pressure or density, as in diagrams 7 and 8, Plate 6. If a pipe conveying steam were turned directly back into the water of the same boiler, it is evident that equilibrium would ensue and no effect be produced. If on the other hand a break were made in the continuity of the pipe so as to leave an interval open to the atmosphere, the steam would rush from one pipe and the water from the other at velocities proportioned to their different densities. But in the construction of the injector the feed water chamber F is placed at this break in the pipe, as shown in diagrams 9 and 10 and Figs. 1 and 4; and this arrangement accounts for the power of the steam to

overcome the resistance to its entrance into the receiving pipe below: for the jet of steam being concentrated on the water at I forces its way through the interval L surrounded by the feed water, by contact with which it is gradually condensed and reduced in volume and velocity until it is entirely converted into water at the throat K; while by this contact with the steam from I to K the feed water has a velocity imparted to it proportioned to the steam pressure in the boiler and its own temperature, and being nearly non-elastic it thus acquires momentum sufficient to overcome the resistance of the water in the boiler.

This explanation will perhaps also serve to account for steam of lower pressures being better adapted to act upon water at higher temperatures, since the lower the pressure of the steam the less must be its velocity in passing from the orifice I to the throat K, and consequently the more time will be given for its condensation, a condition necessary when the higher temperatures of feed water are used. This explanation also agrees with the fact that the higher the steam pressure the more rapid is the stream of feed water into the boiler, since in passing from the orifice I to the throat K at a higher velocity and at a higher temperature, a larger volume and a lower temperature of water are required to condense the steam jet; and its capacity for this water being in proportion to its temperature, the quantity of feed carried into the boiler is proportionately increased.

It has not been attempted to give any calculation of the power obtained by the injector; and indeed the writer has been discouraged from attempting this by the opinion expressed to him by an eminent hydraulic engineer, that the injector is a valuable application of a force which very few persons understand and which has never been explained in books. And when it was found possible with steam of 24 lbs. pressure to inject water into a boiler at 48 lbs. pressure, it was felt that it would be premature to bring forward calculations based upon the result of experiments so hastily made, which require much consideration and discussion before any safe conclusions can be arrived at.

Mr. C. W. Siemens enquired what increase of temperature took place in the feed water in passing through the injector, as this would be a measure of the quantity of steam condensed in the jet, and it was important to ascertain the actual expenditure of power in working the instrument. The theory of its action could then be investigated by ascertaining whether the quantity of steam condensed in the jet was sufficient to impart to the jet of water the velocity required for enabling it to overcome the resistance opposed to its entrance into the boiler: for the velocity imparted would be inversely proportionate to the weights in motion, and 1 lb. of steam would impart to 10 lbs. of water 1-10th of its velocity, if no force were lost from friction and eddies in the jet.

Mr. Robinson replied that there was found to be a rise of temperature of about 60° in the water in passing the injector, the feed water at 100° being raised to 160°. He showed a specimen of the injector, taking it to pieces to show the construction.

Mr. E. A. Cowper asked whether this rise of temperature was measured from the waste water overflowing from the instrument, or from the water in the feed pipe going into the boiler: the latter he considered would be requisite for obtaining the correct result. The instrument was certainly highly ingenious and an interesting subject for investigation as to the principle of its action.

Mr. Robinson said the rise of temperature that he had mentioned had been measured only at the overflow, as there was no means of measuring it otherwise at present.

Mr. F. J. Bramwell asked whether the working of the injector could be so controlled as to have no overflow.

Mr. Robinson replied that the overflow was entirely stopped by adjusting the steam and water in due proportion, which took place in a few seconds after starting to work, and the injector then continued working regularly for any length of time without the least overflow with a pressure continuing uniform; but the overflow could be caused directly by increasing the water supply or diminishing the steam too much.

Mr. W. B. Johnson had seen the injector at work, and was much struck with its perfect action and extreme simplicity; it was started

instantaneously to work without any difficulty, and continued working regularly without the slighest overflow of water; the sight holes could be kept permanently open after it was started in full work, and all that was seen was an apparently solid column of water rushing from one tube into the mouth of the other. He saw an experiment tried whilst the injector was in full work, by inserting a plate between the two orifices to stop the action of the jet; but the stream was instantly established again on removing the interrupting plate.

Mr. C. Markham said he had seen the injector working on two stationary boilers at Manchester, and its action was certainly most effective and perfect; the supply to the boiler was kept up without any interruption or difficulty. Its action was no doubt due to the high velocity imparted to the feed water by the steam jet, which was sufficient to carry it into the boiler. An important practical advantage of the instrument was that there was nothing about it liable to get out of order: the only fear he felt was of incrustation from the water accumulating at some part and obstructing the passage through it; for in all boilers a serious incrustation took place around the orifice where the feed water entered, caused by deposit of the earthy matter from the suddenly heated and evaporating water at the moment of entering the boiler: in some cases this incrustation was so great in the course of a short period as to contract a $1\frac{1}{2}$ inch opening to $\frac{1}{4}$ inch or even less in diameter.

Mr. Robinson replied that not the least difficulty of this kind had been experienced with the injector; he had tried after 4 months' work and found no difference perceptible in the diameter of the orifice, and indeed any deposit in the tubes would be inevitably cleared away by the great force of the jet the first time it was started again; and the heating effect of the boiler did not reach the injector. The construction of moveable cones sliding one within the other adopted in the injector effectually prevented any difficulty arising from small orifices, since the actual openings were large, though admitting of regulation down to the smallest size.

Mr. F. J. Bramwell thought the action of the instrument was entirely due to the velocity imparted to the feed water by the jet of steam; it might be illustrated by supposing a cistern of water with

several feet head to supply a jet in the position of the lower part of the instrument, and another jet from a higher cistern to be then brought opposite to the first in the position of the upper part of the instrument, when the greater velocity of the upper jet would necessarily overpower the lower one, and the water would force its way into the tube of the lower jet. Now in the case of the injector, if the velocity imparted by the jet of steam to the feed water in the upper jet were greater than that at which the boiler water would escape from the lower tube if unopposed, the water must be forced into the boiler ; and since the velocity of the steam was so much greater than that of the water issuing from the same boiler, in consequence of its greatly reduced density, the steam jet was able to impart a sufficient excess of velocity to the feed water to force it into the boiler. Increased velocity was indeed in this case made to produce an increased pressure, as in the case of the water ram : only that in the injector the propelling steam was all condensed and got rid of continuously, instead of the actuating water stream being discharged intermittently as in the water ram.

Mr. Robinson observed that a singular circumstance had been noticed in the working of the injector, that when it had got cold it would not start at once, but required warming by blowing steam through for a few moments ; then after shutting the steam off, it started to work all right in two or three seconds when the steam was turned on again.

Mr. F. J. Bramwell asked whether the injector had been tried without having to raise the feed water by suction ; and what difference there was then found to be in the temperature of feed water that could be used.

Mr. Robinson replied that an injector had been in constant use some time at his works which was supplied by a cistern at 20 feet head above it, and there was no difference or difficulty attending its action when the opening for the water supply was regulated accordingly : there was no opportunity for trying the limit of temperature in that instance. That injector was employed in feeding a boiler on the locomotive construction working at 60 lbs. pressure ; and he had also tried one of No. 8 size on a large locomotive engine at 140 lbs. pressure, and it worked perfectly well, and raised the water in the

boiler 3 inches in 4 minutes, the steam blowing off freely at the time.

The Secretary had witnessed many of the experiments with the injector described in the paper, and could confirm the accuracy of the results given.

Mr. H. Maudslay thought that in applying the injector to marine boilers, although its action might be entirely safe and reliable, it would not be advisable to do away with the donkey engines; for independent of their value as an additional precaution they were very useful for other purposes, such as pumping bilge water and as fire-engines, &c.

Mr. Robinson observed that the injector was equally capable of being applied to raising the bilge water or throwing a fire jet, as it discharged a steady jet of water from the delivery pipe; but it was not suited probably as an economical application of power for a fire-engine jet, and the heated water might be objectionable for leather hose.

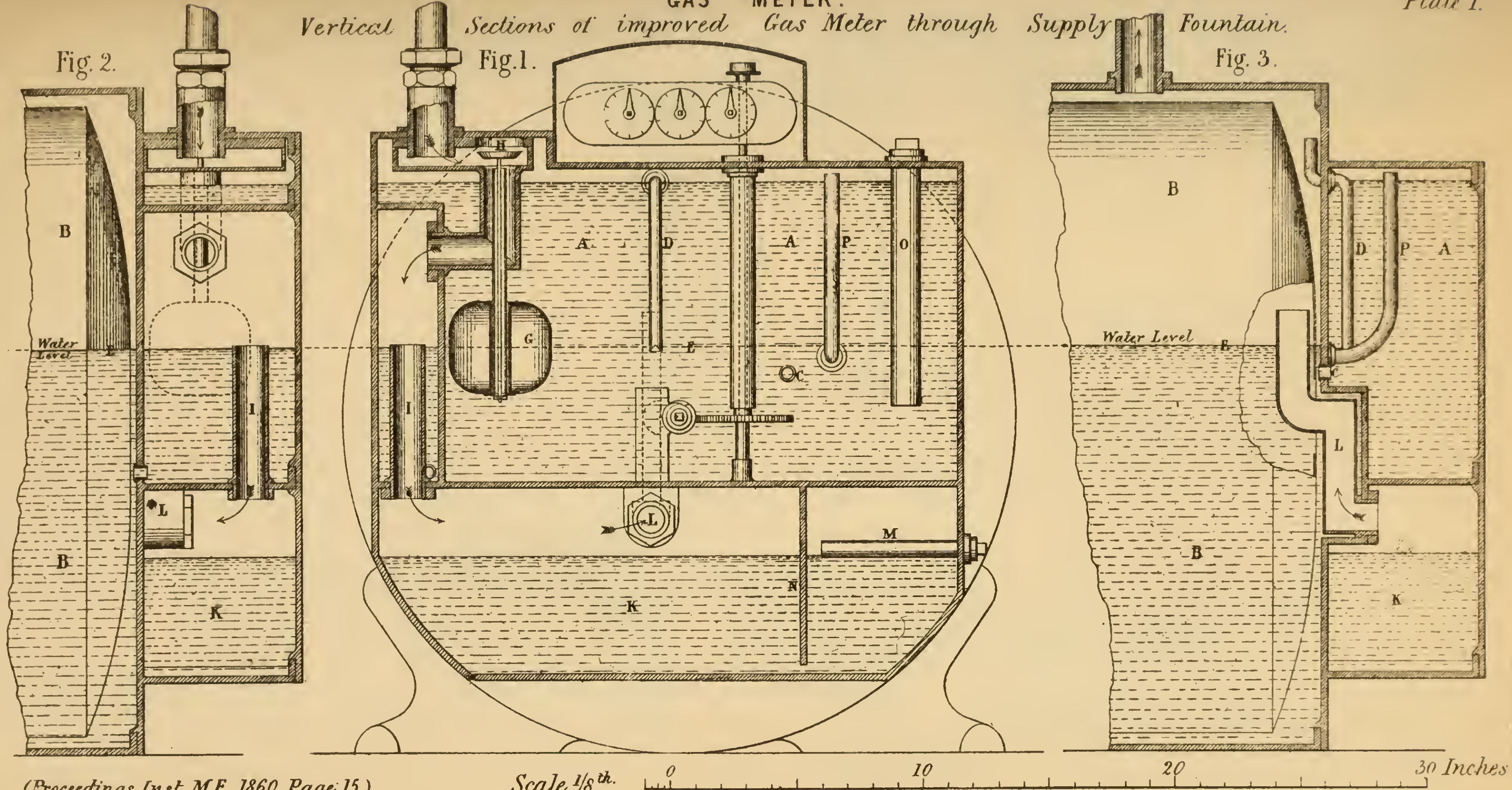
The Chairman proposed a vote of thanks to Mr. Robinson for his paper, which was passed.

The Meeting then terminated, and in the evening a number of the Members and their friends dined together in celebration of the Thirteenth Anniversary of the Institution.

Plate 1.

GAS METER.

Vertical Sections of improved Gas Meter through Supply Fountain.



(Proceedings Inst. M.E. 1860. Page 15.)

Scale 1/8.th

Plate 1.

GAS METER.

Fig. 4.

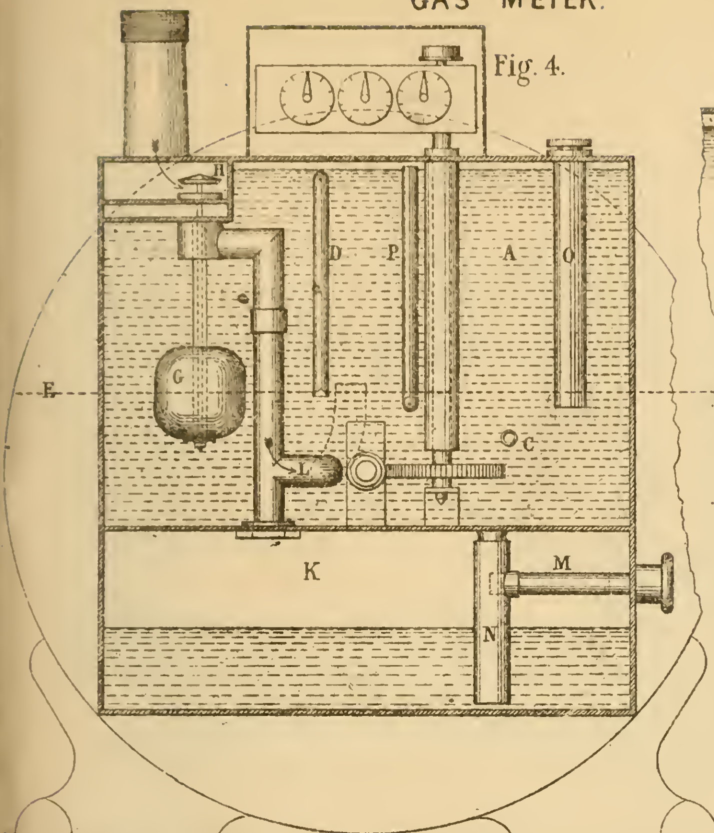


Fig. 5.

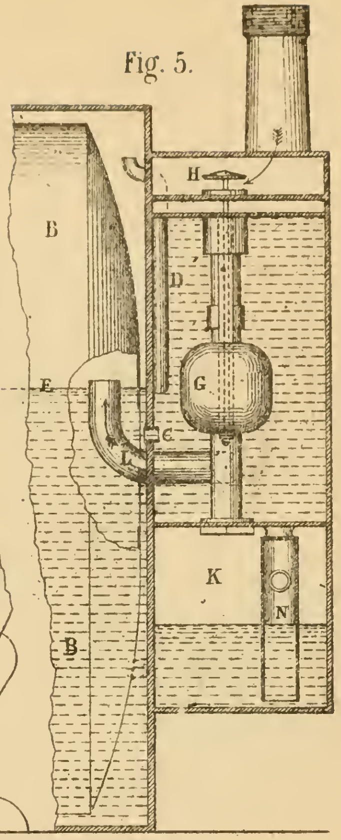


Fig. 6.

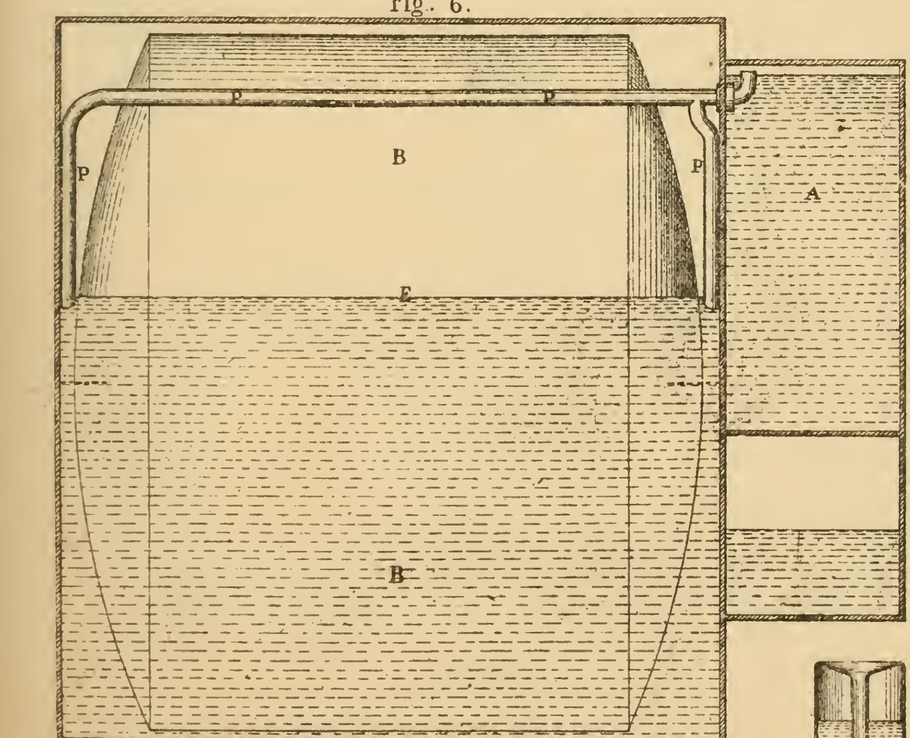
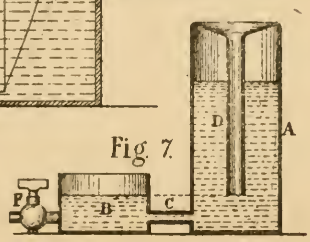


Fig. 7.



Scale 1/8th.

0 5 10 15 *Inches.*

Parson and Pilgrim's Superheating Apparatus.

Fig. 1. *Longitudinal Section through furnace.*

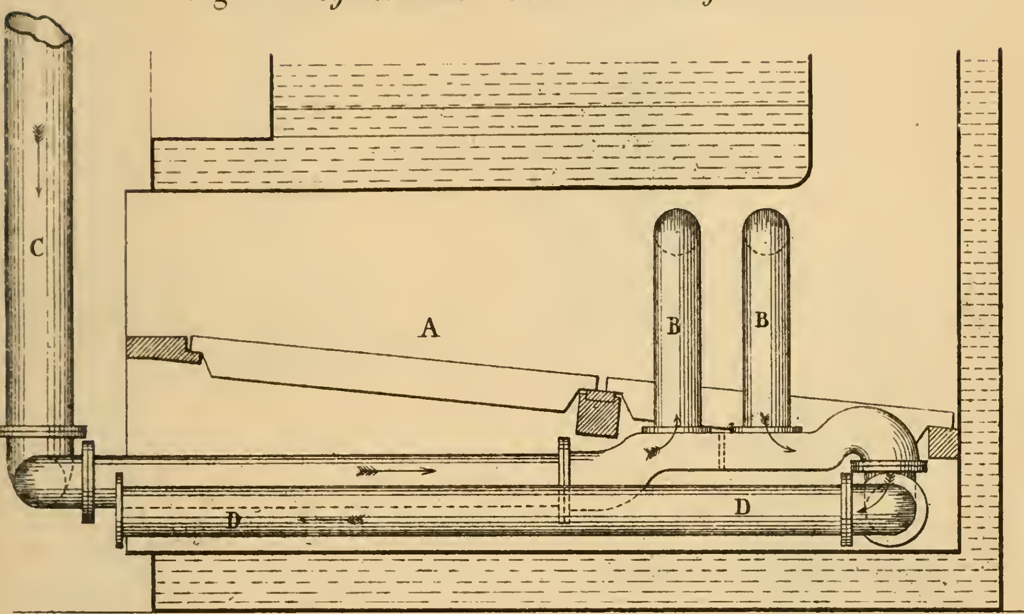
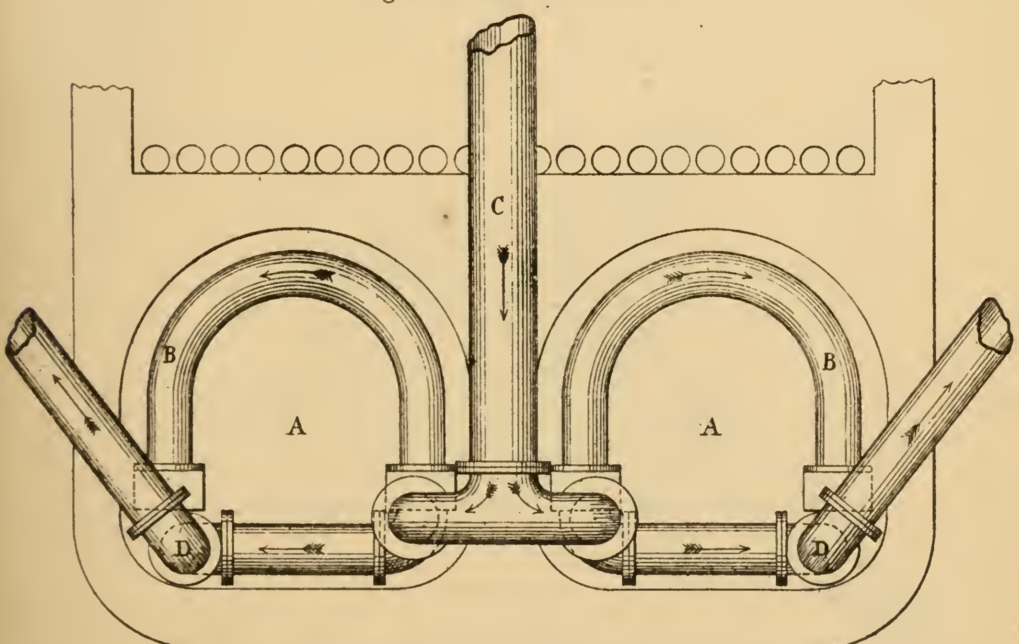


Fig. 2. *Front Elevation.*



Scale 1/25th. *Ins.12 6 0 1 2 3 4 5 Feet.*

Patridge's Superheating Apparatus.

Fig. 3. *Elevation.*

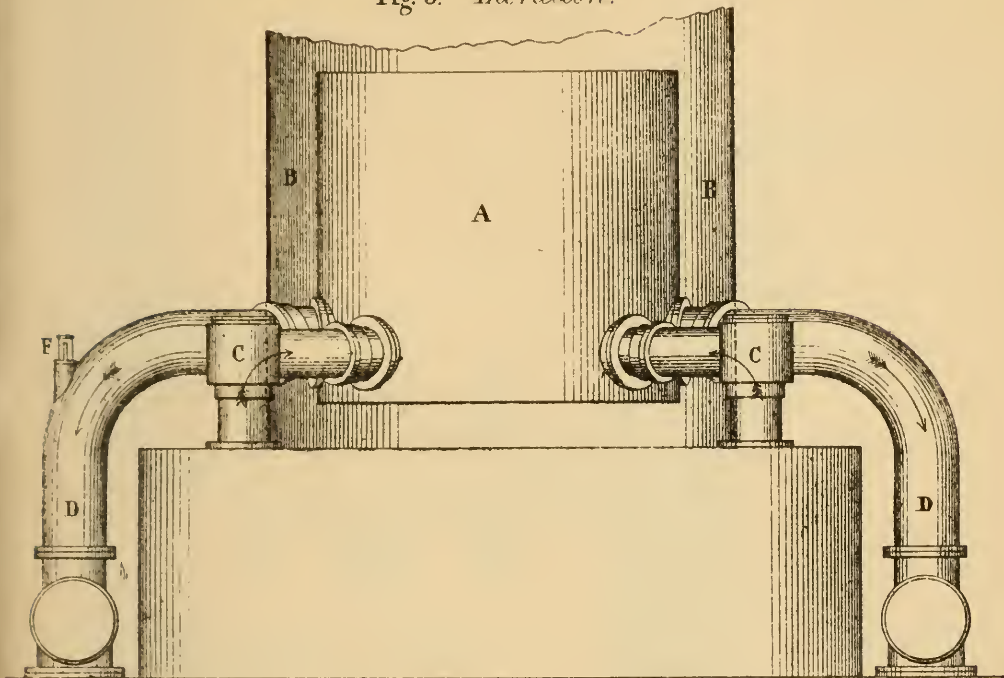
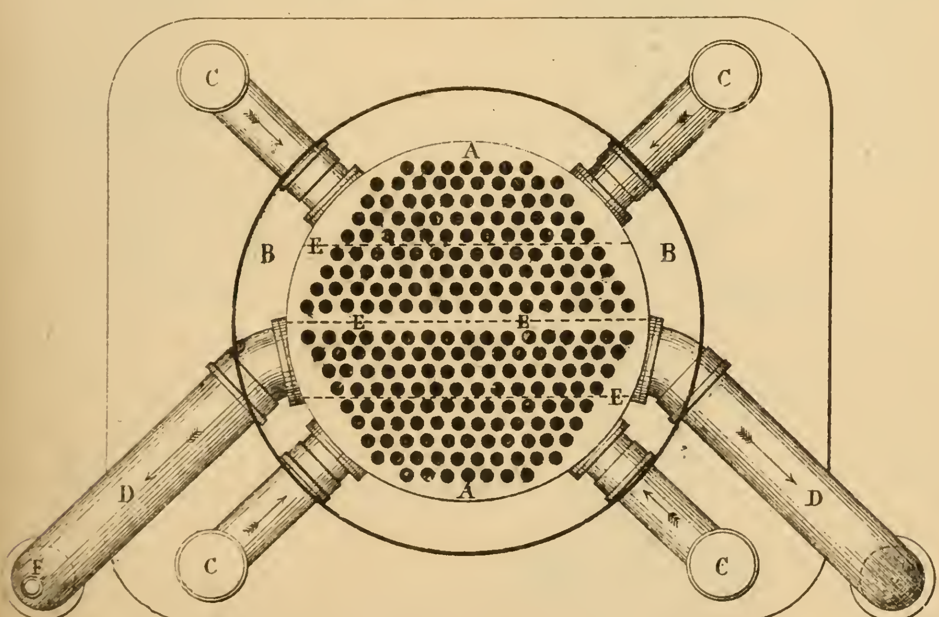


Fig. 4. *Plan.*



Scale 1/25th *Ins. 12 6 0 1 2 3 4 5 Feet.*

(Proceedings Inst. M.E 1860. Page 22.)

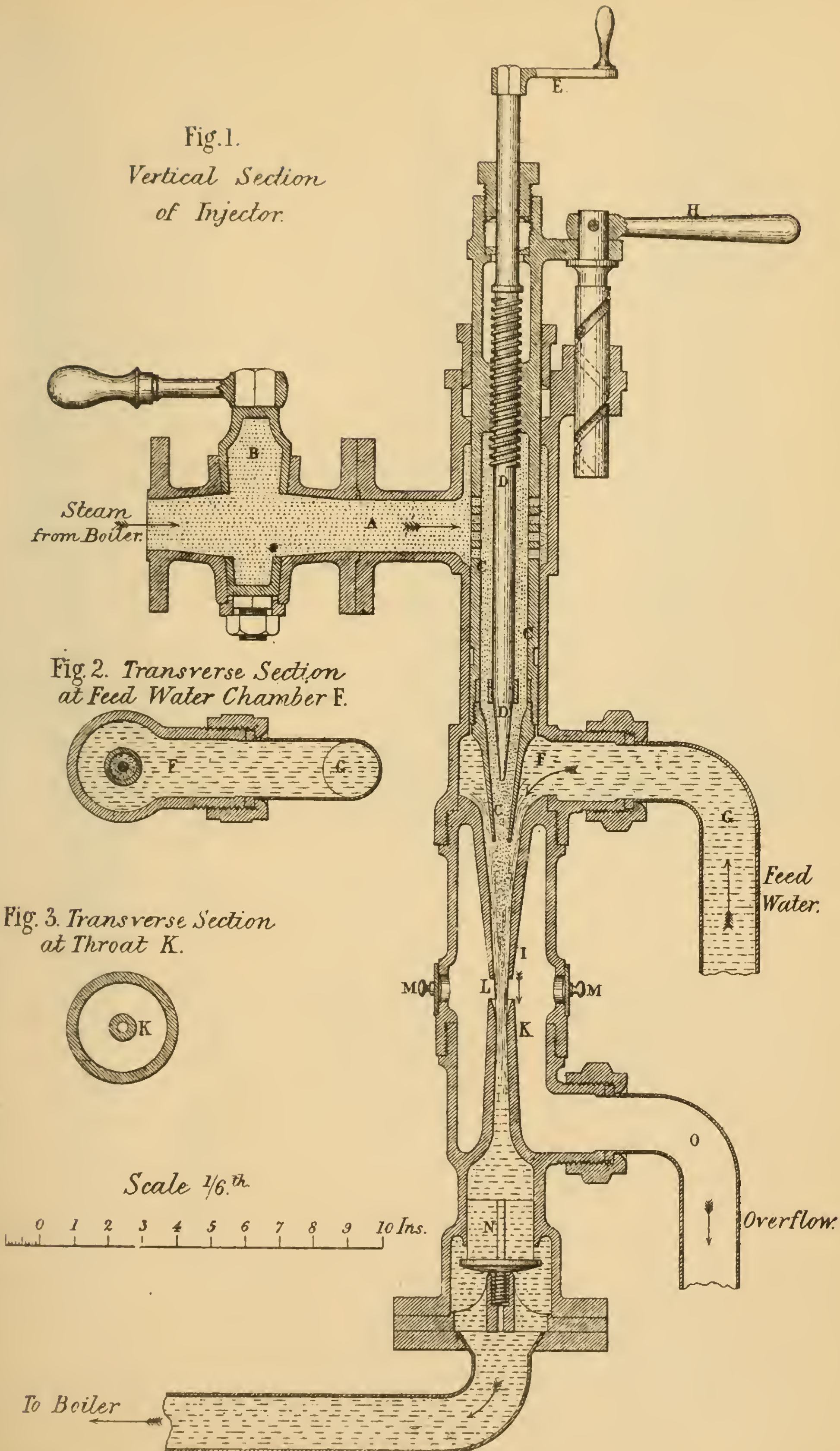


Fig. 1. Vertical Section of Injector.

Fig. 2. Transverse Section at Feed Water Chamber F.

Fig. 3. Transverse Section at Throat K.

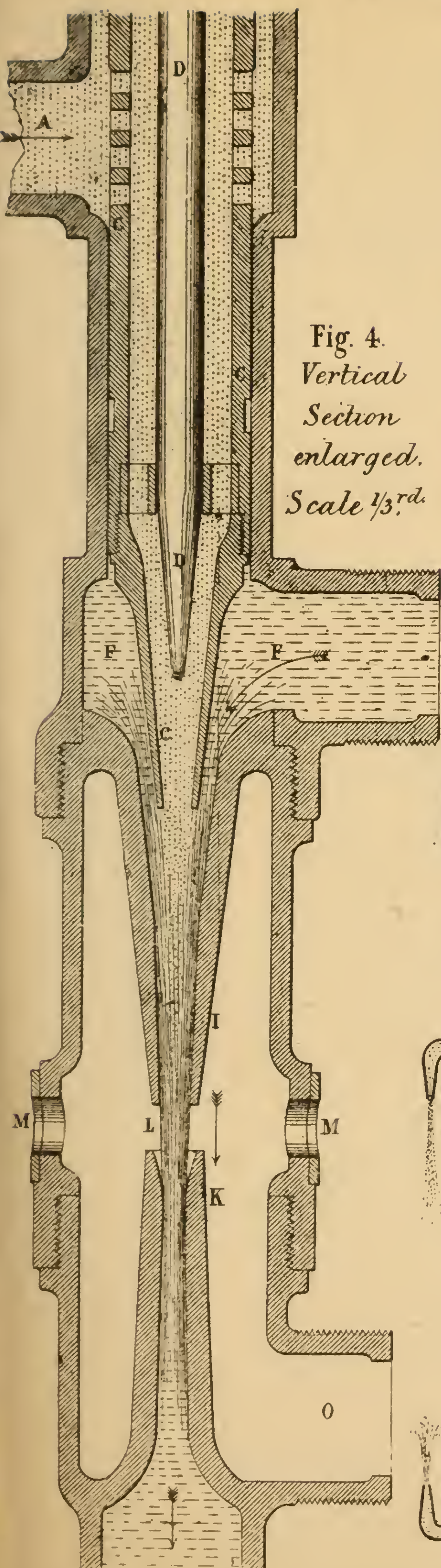


Fig. 4.
Vertical Section enlarged.
Scale 1/3rd.

Fig. 5.
Excess of Steam.

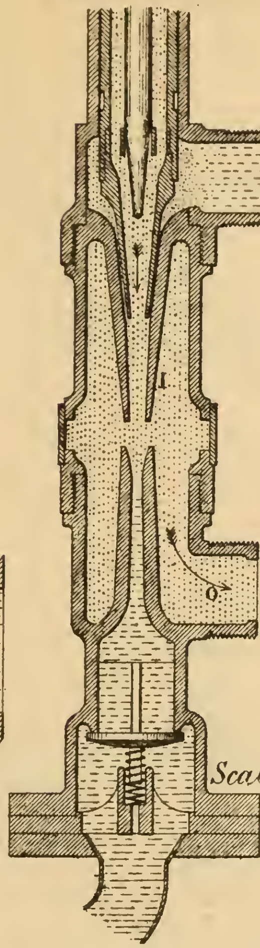
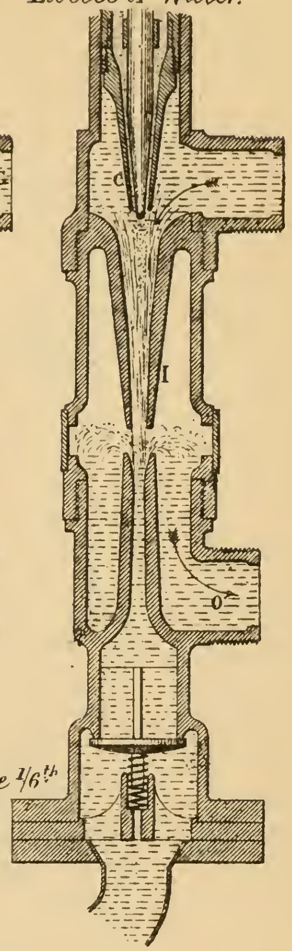


Fig. 6.
Excess of Water.



Scale 1/6th

Fig. 7.

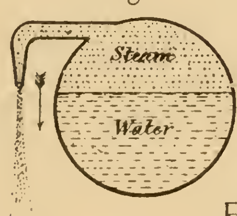


Fig. 9.

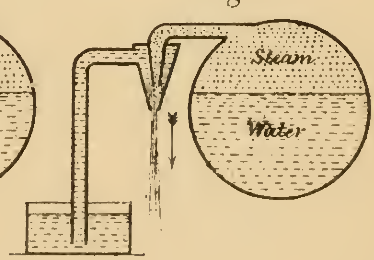


Fig. 8.

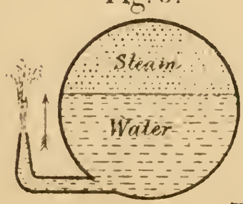
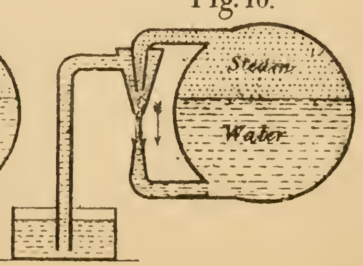


Fig. 10.



BOILER INJECTOR.

Fig. 11. *Injector applied to Stationary Boiler.*

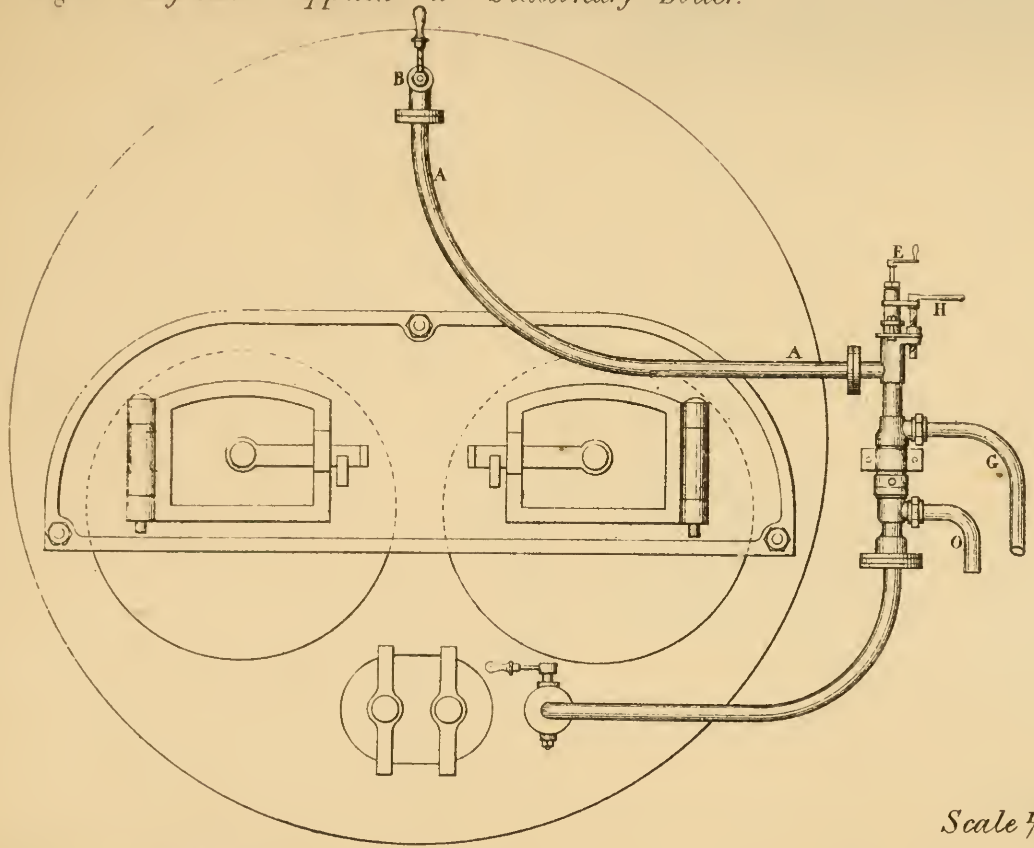


Fig. 12. *Injector applied to Locomotive Boiler.*

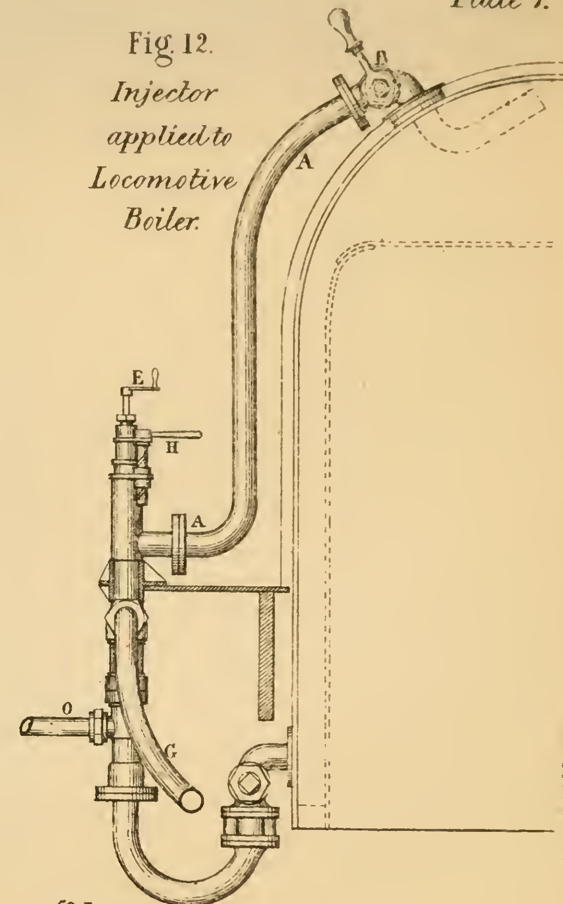


Plate 7.

Scale 1/25th.

0 10 20 30 40 50 Inches.

(Proceedings Inst. M.E. 1860. Page 39.)

PROCEEDINGS.

25 April 1860.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 25th April, 1860; John Fernie, Esq., in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The Chairman announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following New Members were duly elected :—

MEMBERS.

Richard Beck, . . .	London.
Samuel John Claye, . .	Long Eaton.
William Henry Dawes, . .	Westbromwich.
Samuel Jackson, . .	Sheffield.
Joseph Henry Nettlefold, .	Birmingham.
Edward Peyton, . .	Birmingham.
Thomas C. Townsend, . .	Shrewsbury.

HONORARY MEMBERS.

William Hutchinson, . .	West Hartlepool.
Cordy Manby, . . .	Dudley.

The following paper was then read :—

ON SOME REGENERATIVE HOT-BLAST STOVES WORKING AT A TEMPERATURE OF 1300° FAHRENHEIT.

By Mr. EDWARD A. COWPER, of London.

The practical utility of Hot Blast has been so thoroughly appreciated since its first introduction by Mr. Neilson in 1829 that it now needs no advocate to recommend it to experienced ironmasters. Many plans of hot-blast stoves have been suggested and tried, and various opinions have been expressed on their merits; as it has frequently happened that the same constant care and watchfulness have not been exercised at different works, when using stoves of a similar description: some of the best stoves have been described by Mr. Marten in his paper read before this Institution in May last, (Proceedings, May, 1859). It has been found by many careful observers that the results from the blast furnace are so greatly improved by raising the temperature of the blast that ironmasters have often tried how far they could go in obtaining a higher temperature, and have of course soon arrived at a limit from the destruction which ensued of the cast iron pipes; and it is obvious that there must always be a wide difference between the temperature of the air heated inside a cast iron pipe and the fire outside the pipe heating it, as there will be the difference in temperature between the fire and the pipe, together with the difference in temperature between the pipe and the air passing through it. These differences must be considerable, in order to ensure a tolerably rapid conduction of the heat; so that in no case can the hot blast approach at all near to the temperature of the fire, nor indeed would the cast iron stand if anything of the sort were attempted; in fact it is well known what care is necessary in damping the fires of common hot-blast stoves, when the cooling effect of the air inside the pipes is taken away by the blast being stopped at tapping time or on any other occasion. The temperature at which the products of combustion pass away from

ordinary stoves is from 1250° to 1500°, whilst the blast is heated only to about 700°. The economy of fuel for real work done must therefore be very low, as the products of combustion must pass away much hotter than the temperature obtained in the blast, say about double the temperature; and when it is attempted to obtain economy in the blast furnace by increasing the temperature of the blast, economy is further sacrificed in the stoves, by the greatly increased amount of heat which must necessarily pass away: hence the hotter the blast the greater is the waste of fuel in heating it in the ordinary stoves.

In the plan of hot-blast stove to which it is now wished to call the attention of the members, the principle of Mr. Siemens' regenerative furnace is adapted for the special purpose of heating blast, and the stove is enclosed in an air-tight case or skin of metal; by which means it is possible to obtain the blast of as high a temperature as the most refractory material will stand, and to abstract the whole of the heat from the fuel used. The result, it should be observed—great economy with very high temperature—is obtained entirely without any iron surfaces being exposed to an injuriously high temperature, as the whole of the cast iron pipes and mains of ordinary stoves are entirely done away with, and only firebrick or other good refractory material is exposed to the fire; so that the whole of the cost and wear and tear of the cast iron pipes is at once avoided.

It may be well first to refer to the principle of the regenerator, which has been described by Mr. Siemens at a former meeting of the Institution, and which is in successful operation for melting and heating steel and iron, &c. The regenerator consists of a chamber in which are placed a large number of pieces of any refractory material, at a small distance apart, so that the heat from the fire can be passed through the chamber amongst them: they thus become heated, but not equally; for those nearest the fire absorb the greatest amount of heat, then those next to them a somewhat less amount, the next still less, and so on, until at last there is no useful heat left in the products of combustion. For so long as the pieces of refractory material are at a lower temperature than the products of combustion, they will continue to take up some heat, and thus it is impossible for any heat to escape or get through; unless indeed the heating process were continued so

long that the whole regenerator became hot completely through from end to end, which of course might be done, though it would take many hours to accomplish it. The next operation is to abstract or utilise the heat so taken up by the regenerator: and this is accomplished by shutting off the supply of heat from the fire, and turning the air to be heated through the regenerator in the opposite direction; so that it comes in contact first with the cool end of the regenerator, and therefore commences by taking up only a little heat; then as it strikes the next set of pieces of material in the regenerator it takes up a little more heat, as they are a little hotter than the first; and passing onwards it takes up more and more heat as it comes in contact with each stratum of heated material; until the air issues from the hot end of the regenerator at very nearly the temperature of that part, having been again and again broken up into minute streams, and been heated by direct contact with the very surfaces of the material which had previously received the heat: so that whatever heat is first gradually put into the regenerator is again as gradually taken out by the air when passed through in the opposite direction.

The specific heat of common firebrick has been found to be very great, its capacity for heat being about equal to that of copper, bulk for bulk, and therefore many times as great as that of copper, weight for weight. In comparison with water, bulk for bulk, the specific heat is also nearly equal; and the temperature of the firebrick at the hot end of the regenerator being raised to about ten times that of boiling water, this makes the total capacity of the regenerator near the hot end nearly ten times that of an equal volume of boiling water. Now as the specific heat of air is small, being only 1-4th that of water, weight for weight, a small quantity of heated firebrick will suffice to heat a very large volume of air. This is confirmed by practice in the stoves now at work, which have only a moderate quantity of firebrick in them, but the currents of heat and of cold blast require to be changed only once every two hours, to produce a very regular temperature of hot blast; and by increasing the quantity of firebrick or changing two pair of stoves alternately, much longer times of changing might be adopted, or even greater regularity of temperature might easily be obtained. Firebrick is also a good refractory material,

and is cheap; it is therefore well adapted for the purpose of filling the inside of the regenerators.

The new Regenerative Hot-Blast Stoves are shown in Plates 8 to 14. Figs. 1 and 2, Plate 8, are a vertical section and sectional plan of one of a pair of experimental stoves, erected at Messrs. Cochrane's works at Ormesby near Middlesborough, where they have been working regularly for more than two months, heating nearly 1000 cubic feet of air per minute up to 1200° or 1300° Fahr. Fig. 6, Plate 12, is a plan of the pair of stoves placed side by side. These stoves are heated from the bottom by coal fires A, and the heat passes upwards through the regenerator B by which the greater part of it is absorbed, the residue finally escaping at the top through the valve C into the flue leading to the chimney. The fireplace A is provided with a sliding firedoor D, made hollow with water in it, as shown enlarged in Fig. 12, Plate 14, which runs to and fro on rollers, and when shut encloses the fire entirely as well as the ashpit; and being planed to fit its frame, immediately that the pressure of the blast is put on, the door is pressed against the frame and is made air-tight. The cold-blast valve E at the top of the stove is an ordinary sluice valve; and the hot-blast valve F is a cast iron valve of a hemispherical form, the better to resist the heat to which it is exposed; it does not slide on its face, but is simply lifted up and down, being made flat at the edge and sitting on a rounded seat. This valve answers very well, though for very high temperatures such as 1400° to 1800° or more, which it is proposed to reach eventually, it is intended to have water inside the hot-blast valves, as shown in the enlarged vertical section of the hot-blast valve, Fig. 8, Plate 13, where the valve is made of two wrought iron hemispheres welded and turned on the edge, and supplied with a flow of water like an ordinary water tuyere. Whilst heating up, the sliding firedoor D and the chimney valve C are open; and after two hours these are shut, and the blast valves E and F opened, allowing the blast to pass through the regenerator B in the downward direction for two hours, during which time the other stove is being heated, the pair of stoves being situated side by side, as shown in the plan, Fig. 6, Plate 12.

The regenerator B may be composed of any good refractory material in pieces, and is therefore constructed of firebricks laid open, in the manner shown enlarged in Figs. 9, 10, and 11, Plate 14. The temperature produced by the fire is probably about 4000° Fahr., though no exact experiments have been made on this for want of an accurate instrument; and the action of the regenerator is so perfect that the heat escaping through the chimney valve C is only 150° to 250°: indeed the hand may be put right into the flue without the slightest injury, showing that practically all the heat is absorbed by the regenerator. The cold blast entering at the temperature of the atmosphere, or a very few degrees above owing to its compression to 3 lbs. pressure per square inch, becomes heated in its passage downwards through the regenerator to 1300°, and the temperature varies only about 100° or 150° during two hours' work with one stove. These experimental stoves, however, were never intended to work for more than one hour changes, as they have only a moderate quantity of firebrick in them, being made out of two pieces of wrought iron cylinder, 7 feet 6 inches diameter, that were already in existence. These stoves have now been working for more than two months at the temperature of 1300°, supplying one 3 inch tuyere of a large furnace, and delivering nearly 1000 cubic feet of air per minute. The melting of lead by the blast is a common test for the temperature of the blast in ordinary hot-blast stoves, and with a hotter blast zinc is used as a test; but with such hot blast as is obtained by the regenerative stoves it is necessary to use a metal that melts at a much higher temperature, and therefore antimony is employed, which is melted in some 6 or 7 seconds, and often in even 4 or 5 seconds. The whole of the hot-blast main conveying the blast from the stove to the globe pipe near the furnace is lined with firebrick, as shown in Figs. 1, 2, and 8, Plates 8 and 13; and the muzzle and globe pipe that are not so lined keep red-hot.

Several experiments were made with these stoves last year, but owing to the great distance that the hot blast had to travel through pipes not sufficiently lined with firebrick, several hundred degrees of heat were lost in the passage, since upwards of 65 feet length of cast iron pipe was kept at a good red heat by the passage of the blast

through it. The temperature of the blast at the muzzle in these experiments was often 1250°, whilst at the stove it was 1500° and even 1600°; and at one time, when the stove was pushed too much through carelessness, the blast was heated to within a few degrees of 2000°. With regard to the economy of these fire heated stoves, it may be judged of by the consideration of the fact, that the heat passing away into the chimneys of ordinary hot-blast stoves amounts to about 1250°; whereas with the regenerative stoves it is only 200° or even less.

The mode of measuring the temperatures obtained was by a very simple and accurate pyrometer on the principle of that shown at a former meeting of the Institution by Mr. John Wilson (Proceedings Inst. M. E., 1852, page 53), though perhaps slightly improved in detail. The pyrometer is shown in Figs. 13 and 14, Plate 14, and consists of a copper vessel G capable of holding rather more than a pint of water, and well protected against radiation by having two double casings around it, the inner containing air, and the outer filled with felt. A good mercury thermometer H is fixed in it, having in addition to the ordinary scale a small sliding scale I graduated and figured with 50 degrees to 1 degree of the thermometer scale; there is also provided a cylindrical piece of copper J, accurately adjusted in size so that its total capacity for heat shall be 1-50th that of a pint of water. In using the pyrometer, a pint of water is measured into the copper vessel G, and the sliding pyrometer scale I is set with its zero at the temperature of the water as indicated by the mercury thermometer H; the piece of copper J is then put into the current of hot blast, the temperature of which it is wished to ascertain, and is allowed to become heated for about two minutes, when it is quickly dropped into the water in the copper vessel G, and raises the temperature of the water in the proportion of 1° for each 50° of temperature in the copper; the rise in temperature may be read off at once on the pyrometer scale I, and if to this is added the actual temperature of the water as shown on the scale of the mercury thermometer, the exact temperature of the blast is obtained. This pyrometer is found to be far more accurate than any others for high temperatures, that is such temperatures as will not melt platinum.

Figs. 3, 4, and 5, Plates 9, 10, and 11, show an elevation, vertical section, and sectional plan of a gas stove, to be heated by the waste gas from the top of the blast furnace. Fig. 7, Plate 12, is a plan showing the pair of gas stoves combined. Two pair of these gas stoves are now being erected at some large ironworks in the north of England for blowing a large furnace; they are designed to heat 6000 cubic feet of air per minute to 1300° or 1400°, and to be worked at four hour changes. The entire stove is encased in an air-tight iron casing or skin to confine the blast within the stove, while the firebrick lining of the casing serves to keep in the heat. The drawings show the stove during the time of heating up the regenerator, when the gas valve K and the air valve L immediately behind it are both open for the admission of gas and air to be burnt in the stove at A, as in an ordinary stove using the waste gas from the tunnel head. The gas passes into the stove in a central jet at A and there meets with the air that is entering through the annular space M all around it, and on being lit it forms a large flame right up the centre flue N, which turns over at the top inside the dome and passes downwards on all sides through the regenerator B which entirely surrounds the centre flue N, heating the regenerator in regular gradation downwards, until all the useful heat is absorbed; thus the upper part of the regenerator is very hot, whilst the lower part is very cool. The residue of the heat passes out through the bottom of the regenerator into the circular flues O O and thence through the valve C into the chimney P. A large safety valve R is provided immediately below the gas jet A, as a precaution in case of explosion.

Should it be wished to obtain the very highest possible temperature, this arrangement of heating the regenerator from the top causes those bricks which are subjected to the greatest heat to be free from any pressure, whilst the bricks at the lower part of the regenerator which are subjected to pressure are not required to stand any high temperature. Another advantage of this arrangement is that, even if the area of the spaces between the bricks of the regenerator is very great, there can be no tendency in the products of combustion to mix together in the regenerator, that is for cooler portions to become mixed with hotter portions: for if any portion were to be slower in descending than the

rest, it would from this very cause give off more of its heat and thus become heavier; whereas if any part descended quicker than the rest, it would not lose its heat so fast, and would therefore remain somewhat lighter and its descent would thus be retarded. The same is the case when the circumstances are both reversed, namely, when the cold blast is being heated and is ascending; therefore under this arrangement the currents may be as slow as possible, or the regenerator as large as possible and yet no mixing will take place between the several strata of temperature. It may also be observed in reference to the heating of the regenerator that as the hot end approaches the temperature of the fire whilst the cold end is at the temperature of the chimney flue, so the temperature of either end varies but little, even after several hours' heating, though the heat works further in at the hot end and there is less length of cold part at the cold end; the regular scale or gradation of temperature of the great bulk of the regenerator is simply shifted lower down in the mass of brickwork, there being a greater length of hot part then left at the upper end. When the stove has been heated for two, four, or six hours, the gas and air valves K and L are both shut, and the chimney valve C also; then the cold-blast valve E and hot-blast valve F are opened, and the blast at once commences passing up through the regenerator and being heated. Precisely the opposite result now takes place in the gradual shifting upwards of the scale of temperature in the regenerator; until by the long continued action of the cold blast in taking up heat from each course of bricks in succession there is only a short length of thoroughly heated part left at the top, and a greater length of cooled part left at the bottom of the regenerator, when it is time to change the valves again.

When changing the stoves it is the practice of course to put the blast on through the fresh stove before shutting it off from the first, and so for a few seconds half the blast passes through each stove. With full size stoves the changing will probably take place every four or six hours, according to the degree of variation that it is thought proper to allow in the temperature of the blast. The stoves shown in the drawings do not contain quite so much brickwork as would be used if it were intended to work at longer times of changing.

The friction or resistance to the blast in passing through the regenerative stoves is not more than through the ordinary stoves, producing a reduction of only about $\frac{1}{10}$ lb. per square inch in the pressure of the blast.

The economy of heat obtained by the new stoves as compared with the ordinary is most striking when using gas as fuel: for it has been found by direct experiment that the heat passing away from the ordinary stoves amounts to more than 1250°, and as the temperature produced by the combustion of the gas is about 2000°, the difference or about 750° is all the heat that is taken up by the ordinary cast iron pipes; whereas the regenerative stoves do not part with the heat at a higher temperature than about 200°, and as the temperature produced is about 2000°, the difference or 1800° is used in place of only about 750°.

The advantages that may reasonably be expected from the regenerative hot-blast stoves are twofold. Firstly, supposing that it is only required to use blast of the usual temperature, the advantages of this plan are the substitution of cheap firebrick surfaces to receive the heat of the fire, in place of the more costly and perishable cast iron pipes, so that all burning out of pipes and leaky joints are at once saved, while, surface for surface, firebrick is only 1-100th part of the expense of cast iron pipes; there is also great economy in fuel, resulting from the fact that all the heat is absorbed in the regenerator before passing away to the chimney. Secondly, the greatest advantage consists in the power obtained of raising the temperature with perfect ease to a much higher degree than ever could be attempted before, and this too with the greatest possible economy of fuel and materials.

As regards utilising the waste gas from the top of a blast furnace, recent experience both in this country and abroad has fully proved that there is no real difficulty in accomplishing this, either on the plan adopted at the Ebbw Vale works or on that of Mr. Charles Cochrane, and all doubt on the subject is now removed. The regenerative stoves are particularly well adapted for being heated by gas, as there are no iron pipes to be injured by the gas flame. If it be urged that there is already more gas generated from one furnace than is enough to

heat the blast for it and that therefore it is unnecessary to think of economy, it must be borne in mind that when the quantity of fuel in the furnace has been reduced to a minimum by the use of very highly heated blast, there will probably be only just enough gas made to heat the blast to the desired temperature, as well as to supply the various boilers for blast and lift engine, foundry purposes, &c.; when this has been done, the quantity of fuel consumed per ton of iron made will be exceedingly small, as there will be no heat lost beyond the radiation and that taken away by the melted iron and the cinder.

There are other considerations worthy of the attention of iron-masters with respect to the regenerative hot-blast stoves, such as the decidedly increased make of iron that will result from a furnace of a given size; the greatly improved power of dealing with certain kinds of ironstone; and the advantage of being able to keep out a large quantity of the impurities always introduced in the fuel, such as sulphur, phosphorus, &c., and thus obtain a better quality of iron. The author will not however at the present time attempt to enter into the detail of these matters; for it is certain that a large saving of fuel will be effected, probably equal or nearly so to that produced by Mr. Neilson's original and admirable invention of the hot blast itself: but if it eventually should prove that this is a first step towards any improvement in the manufacture of such an important article as iron, he will feel great satisfaction in the fact that this Institution has always taken the lead in inquiring into any practical improvement in its manufacture.

Mr. Cowper showed a working model of the stove in operation consisting of a fireclay cylinder with open ends, having a grating at the bottom; it was filled with broken pieces of firebrick, which were heated by a gas burner below, until the lower layers of firebrick became red-hot. The two ends of the cylinder were then closed air-tight, and a blast of hot air was forced in at the top from an india-rubber reservoir, which issued at a side jet near the bottom of the cylinder; the heat of the blast at the jet then melted lead, although the heat at

the top of the cylinder at the same time was so low that the upper layer of firebricks was only slightly warmed, and the paper funnel which had been used as a chimney to the stove was not marked or scorched in any way.

In working the pair of coal-burning stoves heating the blast alternately, as described in the paper, some difficulty was anticipated at first in preventing the fire from burning away during the period that the stove was shut and the blast passing through it; but it was found that the fire being situated out of the line of blast was isolated for the time, and the blast did not pass over it, so that the fire became smothered in an atmosphere of carbonic acid gas, and lay smouldering until the next change, the blast passing across the opening of the fireflue but producing no draught through it as the firedoor was closed. When the blast was turned off and the firedoor opened, the fire was at a dull red; and fresh fuel being thrown on, it burned up at once and began to heat up the regenerator again.

There was no difficulty in preserving the bearing bars of the firegrate from giving way whilst exposed to the high temperature of the blast for two hours, for by using water pipes as the bearing bars with a constant stream of cold water running through them they stood perfectly; the sides of the fireplace were also similarly protected by water boxes, and the sliding door was made hollow with water inside, having india-rubber water pipes to and from it like a water tuyere, allowing the required extent of motion to the door. This construction had proved quite successful in preventing any injury from the intense heat, and the circulating water flowed away only moderately heated: it was proposed also to use hollow valves filled with water for the hot-blast valves in the stoves now about to be put up, in which still higher temperatures would be employed.

Mr. C. W. Siemens explained the action of the pyrometer employed for measuring the high temperatures of blast that had been obtained with the new stoves. A pint of water having been accurately measured and poured into the vessel, the sliding scale of the pyrometer was set up with the zero mark at the temperature of the water as shown on the scale of the mercury thermometer; and a cylindrical piece of copper, made of such a size that its total specific

heat should be 1-50th that of a pint of water, was held on a wire and put into the ordinary testing hole behind the tuyere, and held in the blast for two minutes. It was then suddenly thrown into the vessel of water, and the rise of the mercury thermometer in the water was read on the pyrometer scale, which was graduated in proportion to the relative specific heat of the copper cylinder and the pint of water, so that each degree of temperature of the mercury thermometer was read as 50 degrees on the pyrometer scale; then by taking the reading of the pyrometer scale and adding the reading of the mercury thermometer for the actual temperature of the water, the exact temperature of the blast was obtained. This pyrometer had now been tried practically for some time for these stoves as well as for stoves of the ordinary construction, and answered correctly for indicating the temperature: for still higher temperatures a piece of platinum would be used instead of copper, and the instrument would then be available up to the highest temperature that platinum would stand.

Mr. J. B. Neilson said it was always a great pleasure to him to see any improvement made in connexion with hot blast, as he had taken so strong an interest in its extension ever since first inventing it more than thirty years ago. He was much struck, on hearing the paper on hot-blast ovens by Mr. Marten read at a former meeting, with the value of the magazine of heat that existed in the large firebrick core filling the centre of the oven then described, which had the effect of regulating the temperature of the oven, preventing fluctuations arising from irregularities of firing: and in the new regenerative ovens that had now been described, the great capacity of firebrick for heat had been well taken advantage of, and a very important step in advance had been made by giving the means of raising the temperature of blast much above the extreme limit practicable with the present ovens, and he considered this would be productive of the greatest benefit in the working of the blast furnace.

The great improvement effected by the use of hot blast lay in raising the temperature in the blast furnace to such a degree that there was always a sufficient margin of heat above the point of fusion of the iron ore to ensure regularity in the make of iron: for in cold-blast furnaces the heat could only just be raised to the melting point

of the ore, and the least deficiency of fuel or a slight increase of moisture in the blast lowered the temperature below the melting point and interfered with the proper working of the furnace; so little indeed was the heat obtained in a cold-blast furnace above the melting point that even the additional moisture contained in the blast on a hot day was sufficient to bring on a change from white to black slag in the working of the furnace. But the use of hot blast gave a great additional power of managing the furnace, by raising the temperature so much above the melting point that no fluctuations ever brought it down low enough to cause injury. The great advantage of hot blast in this respect became sufficiently apparent even when the temperature was raised only 50° to 100° in its first applications; and therefore the very great increase of temperature now obtained in the new regenerative ovens must be expected to be attended with most valuable results in increased yield of furnace and superior quality of pig, owing to greater regularity of temperature in the furnace. There might perhaps be some little trouble at first, he thought, in managing the alternate working of a pair of ovens, but this would soon be got over: the great point however in the regenerative ovens was that the whole heat of the fuel was there taken up, and given out into the furnace by the blast. Where high heats were employed with the present ovens a great amount of heat was lost by passing off to the chimney, which it was not possible to take up and make use of in the present construction of ovens; but in the new oven it was astonishing how small a quantity of heat escaped into the chimney, and this must cause a great saving of fuel. The high temperature of blast of 1300° obtained in the regenerative ovens appeared at first scarcely credible: but the statements that had been given of their construction and working showed that this temperature was quite practicable, and even higher temperatures might be attained. He had always wanted to get a very high temperature of blast, and was convinced that, now the advantages of increasing the temperature of hot blast had been so clearly established by experience, advantage would be taken of every means to raise it still further. The only question on which he felt some doubt at present was whether the inside of the blast furnace would stand the very high heat obtained: for before bringing out the invention of the

hot blast he had tried its effects in a small furnace 3 feet high and 12 inches diameter, in which he got the temperature up high enough to melt the scoria from copper works, and obtained No. 1 cast iron from it; but the inside of the furnace was also melted down by the very high temperature. But even if the heat should prove so intense as to make it difficult to keep the furnace in order, it might still be practicable to get over this by some plan of water casing to protect the sides of the furnace from injury. In this small experimental furnace the first spiral water tuyere was used, imbedded in fireclay, which was now replaced by the cast iron water tuyere.

There was another advantage he believed attendant upon the increased temperature of blast obtained with the regenerative ovens, which consisted in lowering the height of the point of fusion above the tuyeres. By the present use of hot blast the melting point was already brought down to within say about 8 inches of the tuyeres; and with the blast raised to 1300° or 1500° he thought it would probably be within 2 or 3 inches of the tuyeres, which would prevent the newly melted iron from being exposed so long to oxidation by the blast, and thereby save waste of iron in the furnace. The saving in fuel effected by the regenerative ovens would be twofold, since there would be less fuel required for heating the blast now that all the heat was made use of, and also less fuel and lime consumed in the blast furnace, owing to the increased temperature of blast; while at the same time more iron would be produced in the time and of more uniform quality. He did not think there was any danger to be apprehended of injuring the quality of iron by using a hotter blast; for some years ago it was feared by many that if the blast were heated above 300° the iron would be spoilt for foundry purposes; but now it was already heated to 700° or 800° without any such detrimental result being experienced, and he therefore looked forwards to the use of still hotter blast without fearing any injury to the iron.

The regenerative system, which had been so well carried out in the ovens now described, appeared to him to be applicable with advantage to a great variety of manufactures where at present a great amount of heat was wasted by being allowed to escape into the chimney, which might be intercepted and made use of by means of a regenerator. He

thought the application of the plan to gas retorts would be very desirable, for at present the heat in the flues escaped into the chimney as hot as the retorts themselves and almost as hot as the fuel.

Mr. C. W. Siemens thought the hot-blast stove that had been described was one of the most complete and satisfactory applications of the regenerative system yet made ; the perfect regulation of blast obtained by it and of the chemical operations in the blast furnace was a highly important point of superiority over the present stoves. He had been for many years working at the introduction of the regenerative principle, in order to utilise the whole of the heat given out in the combustion of fuel, and had applied it already in furnaces for heating and melting glass, iron, and steel, in some cases with great success. The difficulty attending its adoption had never been with the regenerator itself, but in the mode of carrying out the special application, so as to accommodate it to the particular requirements of each manufacture.

For heating the regenerator he was decidedly in favour of using gas instead of coal: for a coal fire gave out a very great and unnecessary heat in the fireplace by radiation, requiring special protection of that part to prevent injury; while gas produced less heat at the actual point of ignition, but quite a sufficient temperature in its combustion. In these hot-blast stoves the regenerative system was carried out very well indeed, particularly in the coal-burning stove, considering the difficulty of shutting in the fire while the blast was on: but in firing with gas this difficulty was done away with; the gas valve was simply shut at the time of change, and all the flame went out, and was then lighted again at the next time of heating up the regenerator. In working the regenerative stoves he thought it was not desirable to get up an intense heat much beyond that to which the blast was required to be heated, in order not to expose the material of the stoves to an unnecessarily high heat, and on this account gas appeared preferable to a coal fire ; for gas in burning gave a temperature of about 2000° and would heat the hottest end of the regenerator to that degree, and then in the return course the blast could be heated nearly to the same temperature, which was at present quite as high as could be made use of. He was so convinced of the superior

advantages of gas for heating, that in some cases where he had not got the waste gases from the blast furnace to use he had purposely made gas producers, in order to obtain gas from the fuel for burning instead of burning the fuel direct. A large quantity of fuel was laid on a grate in a very thick layer, say about 3 feet thick, and ignited from the bottom, with a slow current of air passing up through it; then as the carbonic acid formed at the bottom passed upwards through the fuel above, it formed carbonic oxide, which passed off at a moderate temperature of about 300°, mixed with the carburetted hydrogen distilled from the coal, and was conveyed to the stove where the heat was required, and there burnt by admitting the required proportion of atmospheric air.

Mr. C. Cochrane observed that the hot-blast stoves put up at his works at Middlesborough were heated with coal fires as had been described; but where there was any difficulty in burning coals he could confirm the advantage of using gas for heating the stoves. He had seen one of the regenerative gas furnaces employed at Messrs. Naylor and Vickers' works at Sheffield for melting steel, which was working successfully.

Mr. J. B. Neilson asked what were the cubic contents of the firebrick contained in the regenerator in these hot-blast stoves, and the quantity of fuel required to heat them, with the time of heating and the quantity of blast passed through. At present about 5*s.* per ton of iron made was the general cost for heating the blast to the temperature of about 700° or 800°.

Mr. C. Cochrane replied that each of the new stoves at his works was 9 feet deep and 5 feet 10 inches diameter, containing 250 cubic feet of firebrick, and heating 1000 cubic feet of air per minute to 1200° or 1300°, the temperature falling to 1150° at the end of each change, or only 150° variation of temperature altogether; the stoves worked alternately, being changed every two hours. As regarded the consumption of fuel for heating the blast, the result of eight weeks' work was a consumption of 6 cwts. of coal per ton of iron with the new stoves, instead of 5½ cwts. with the ordinary stoves; but then with ½ cwt. more in the new stoves the blast was heated some 350° higher. In the present case however the new

stoves had been working under considerable disadvantages, and there were some defects in construction that would be corrected in the next stoves made on this plan. The iron casing of the stoves was lined with only 9 inches thickness of firebrick, which it was afterwards found ought to have been 14 inches at least; and the fireplace was 3 feet further than it need have been from the stove, as it had been proposed at first to introduce a damper between the fire and the regenerator, in order to shut off the fire when the blast was on, but this was found to be quite unnecessary. When the new stoves were tried under proper conditions without these disadvantages, and of large size instead of small, he was satisfied that great economy of fuel would result.

Mr. H. Marten was much pleased to see this further extension of Neilson's original idea of the hot blast, and was convinced that great improvement might be made over the present stoves, so as to obtain a hotter blast. There had been no experience yet of the regenerative stoves in the Staffordshire district; but it was clear that when radiation was so thoroughly prevented as in this case, all the heat imparted to the brickwork must be communicated to the blast and go into the furnace, which would produce great economy of fuel besides giving a much hotter blast than was practicable with the present stoves. He enquired what was the cost of the new stoves.

Mr. Cowper replied that the cost of a complete set of four stoves for heating 6000 cubic feet of air per minute for one blast furnace would be about £1800 if heated by fires, and a set of four gas stoves would cost about £1400: but if the stoves were made larger so that two would be sufficient for a furnace, the cost would be less. The cost of heating the blast by the new stoves would not be more than one half or one third he believed of that with the ordinary stoves, while the blast would be heated up to 1200° or 1500° instead of only 700° or 800°.

Mr. H. Marten observed that the cost of the present oval ovens of the most economical make as erected at the Parkfield Iron Works was about £500 or £600 for supplying 7 or 8 tuyeres with blast at a temperature of 700° or 800°, and the consumption of fuel was generally about 6 to 7 cwts. of slack per ton of iron made. The iron

heating pipes in the present ovens were reckoned to last about seven or eight years with no material repairs; but the new regenerative ovens described in the paper would certainly be less liable to want repair, as there were no iron pipes or joints to leak in them, and the interior was made entirely of a very indestructible material.

Mr. SAMUEL LLOYD asked whether any increase in make of iron had been caused by the new stoves. They had made a trial of a considerable increase in temperature of the blast some years ago at the Old Park Iron Works, and heated it up to about 900° by passing it through a second ordinary stove near the tuyere; but the make of iron was not found to be increased as compared with that produced at the ordinary temperature of 600° or 800°.

Mr. C. COCHRANE said the make of iron had been the largest whilst the new stoves were used, but the effect was not at present sufficiently marked to enable him to state whether it was due solely to the increased heat of blast. The new stoves had been put up to test the practicability of applying the regenerative principle and supplied blast to only one tuyere out of five, so that the addition of 350° to the blast at one tuyere was equivalent to only 70° at each tuyere, which was little more than the fluctuations of temperature that the furnace was already exposed to with the ordinary stoves, and not enough to afford definite results. A high heat of blast could not be tried properly with the ordinary stoves, as the iron heating pipes would soon be melted down with any great increase of temperature beyond that at present obtained with them.

Mr. J. B. NEILSON had no doubt the make of iron would be considerably increased by the higher temperature of blast given by the regenerative ovens; for in his first experiments on the use of hot blast, though he could not get more than 70° or 80° rise of temperature, this was enough to produce a decided increase in make of iron. He was therefore in favour of heating the blast to as high a temperature as practicable; possibly if a blast sufficiently hot could be employed the iron ore might be melted with lime only, without any coal except what was required to carbonise the ore; provided that the heat in the blast furnace was not so great as to bring down the furnace itself.

Mr. C. COCHRANE said that with the blast heated to 1300° there

had been no difficulty in keeping the breast of the furnace near the tuyere in perfectly good order; and thought there was no danger of melting the furnace down by an increased temperature of blast; for a hotter blast merely reduced the proportion of fuel required in the furnace, and the actual temperature in the furnace need not be increased beyond that of the present hot-blast furnaces, so that there would be no danger of injury to the furnace or to the iron made.

Mr. F. J. Bramwell observed that the regenerative oven now gave the power of raising the temperature of blast to almost any heat desired, far beyond what was ever before practicable; and the heat in the furnace could certainly be regulated to any desired extent by changing the burden so as to prevent any difficulty from the very high temperature of blast. This was the first instance of a hot-blast oven in which the heated blast did not come in contact with the iron casing containing it; the interior was entirely lined with firebrick, and the iron was not exposed to the high heat of the blast, while the oven was made air-tight by the iron casing outside, since no brick casing would be air-tight. The great advantage of the oven in making use of all the heat of the fuel was plainly shown in the working model now exhibited, which made the blast hot enough to melt lead at the bottom, while within little more than a foot the heat escaping at the top was reduced so low as to allow of a paper funnel being used as a chimney. This showed that the heat was thoroughly taken up by the firebrick in the regenerator; whereas in ordinary ovens the heat in the chimney passed away at about 1200°, the very temperature of the blast in the regenerative oven.

The Chairman hoped further particulars of the working of the new stoves would be given when more of them were at work, and when the results of blowing an entire furnace with the increased temperature of blast and also the results of the gas-stoves had been obtained. He enquired what was the amount of royalty upon them.

Mr. Cowper replied that the royalty was 6*d.* per ton of iron made: a set of gas stoves were now being applied to a large furnace in the north of England, on the construction shown in the drawings, and the results obtained when they were got to work would give the means of ascertaining the extent of their economy.

The SECRETARY had seen the stoves at work at Middlesborough, and could confirm the statements given in the paper as to the high temperature of the blast from them and the low temperature in the flue passing from the top of the stoves.

The CHAIRMAN observed that he understood an important application of the regenerative principle was now in progress for the locomotive engines intended for working the underground Metropolitan Railway in London, so that there would be no smoke or fire and the steam would be all condensed.

Mr. C. W. SIEMENS said he had prepared the designs for these locomotives for Mr. Fowler, the engineer of the railway, as an application of the regenerative principle, with the view of carrying a store of heat in the boiler sufficient for the short trip required, so as to dispense altogether with a fire whilst running, thus getting rid of all objection from products of combustion as well as steam being given off from the locomotives.

The CHAIRMAN proposed a vote of thanks to Mr. Cowper for his paper, which was passed.

The following paper was then read:—

ON GIFFARD'S INJECTOR FOR FEEDING STEAM BOILERS.

SUPPLEMENTARY PAPER.

By Mr. JOHN ROBINSON, of Manchester.

In the previous paper on the subject of M. Giffard's Water Injector, read at the last meeting (Proceedings, January, 1860), the results of various experiments tried with the injector were given in Tables I to IV. Table I gave the maximum temperature of feed water which had up to that time been successfully employed with different pressures of steam ; and showed that the lower the pressure, the higher is the temperature of feed capable of being used. Table II gave the quantity of water delivered by a No. 4 injector at different pressures of steam, showing that the higher the pressure, the greater the quantity of water delivered into the boiler. Table III gave the quantity of water delivered by a No. 8 injector at various temperatures of feed water, showing the diminution of delivery as the temperature of feed is raised. Table IV showed the excess of pressure which may exist in the boiler fed by the injector above that of the steam used for working the injector, which is perhaps the most surprising of all the results obtained ; showing that with an opposing pressure more than 50 per cent. in excess the injector still continued to work.

A further series of experiments on the working of the injector have been tried by the writer since the last meeting, the results of which are given in the following Tables V to VIII.

Tables V and VI show the rise of temperature of the feed water in passing through the injector, under different circumstances of pressure and initial temperature of feed :—

TABLE V.

Rise of Temperature of Feed.

Injector delivering into boiler at same pressure.

Pressure of Steam.	Temperature of Feed.	Temperature of Delivery.	Rise of Temperature.	
Lbs.	Fahr.	Fahr.	Fahr.	
15½	80	151	71	Mean 74°
23	74	147	73	
35	78	154	76	
51	80	154	74	
15½	100	172	72	Mean 76°
23	100	174	74	
35	102	180	78	
51	102	182	80	

Average 75°

TABLE VI.

Rise of Temperature of Feed.

Injector delivering into boiler at higher pressure.

Pressure of Steam. Low Pressure.	Pressure of Steam. High Pressure.	Temperature of Feed.	Temperature of Delivery.	Rise of Temperature.	
Lbs.	Lbs.	Fahr.	Fahr.	Fahr.	
27	52	92	170	78	Mean 78°
35	57	78	164	86	
40	57	78	156	78	
51	57	77	148	71	
27	52	110	188	78	Mean 80°
35	57	106	180	74	
40	57	106	188	82	
51	57	106	190	84	

Average 79°

The general result obtained is a remarkable uniformity in the increase of temperature, which amounts to an average of 77°; the extent of variation was only between 71° and 86°, with a range of pressure from 15 to 51 lbs. per square inch, and a change in the initial temperature of feed from 74° to 110°.

Table VII shows the maximum and minimum delivery from the same injector at various pressures of steam, the temperature of feed being constant at 74° : —

TABLE VII.

Maximum and Minimum Delivery at different Pressures of Steam.

Pressure of Steam.	Maximum Delivery.	Minimum Delivery.	Difference.
Lbs.	Gallons per hour.	Gallons per hour.	Gallons per hour.
20	290	130	160
25	320	150	170
30	330	160	170
40	390	195	195
50	455	200	255

The object of this experiment was to ascertain whether in employing an injector for supplying water to a boiler in which the evaporation varies considerably from variation in the work required from the engine, as in the case of a locomotive, there is the power of increasing or diminishing to any considerable extent the quantity of water delivered by the injector : the result shows that such regulation can be accomplished even though the steam pressure remains the same ; and further that the range of variation available increases with the pressure of steam, the minimum delivery at the different pressures varying to a less extent than the maximum delivery.

Table VIII shows that the pressure of steam is less reduced in feeding a boiler by the injector than by a pump with the same initial temperature of feed :—

TABLE VIII.

Reduction of Steam Pressure in feeding by Pump and by Injector.

	Rise of Water in boiler.	Time.	Pressure of Steam.		Reduction of Pressure.
			Before.	After.	
	Inches.	Minutes.	Lbs.	Lbs.	Lbs.
Pump	8	12	25	15	10
Injector	8	11	25	20	5

The result obtained from this experiment may be taken as a measure to some extent of the economy gained in using the injector as compared with a pump; the steam used in the injector imparting all its heat to the water, besides effecting a saving by obviating the friction and wear and tear of a moving machine like a pump, whether this form part of the engine itself or act as a separate auxiliary machine.

From the experience of the last six months in this country as well as on the continent it appears that the injector may be safely and economically employed for locomotive, marine, stationary, and agricultural boilers. For the three former many injectors have been delivered from the writer's works; while for the last a considerable number have been applied in France. Means of employing the power developed in the injector for other purposes will doubtless gradually suggest themselves; and drawings of some new applications have been prepared, but as they have not yet been put to the test of practical utility in this country it is not necessary to particularise them.

Mr. Robinson observed that the last experiment given had been made on one of the boilers of the Great Eastern, for the purpose of ascertaining how much the pressure of steam was lowered when a certain quantity of feed water was thrown in by the donkey pump and then by the injector. The donkey engine first threw in 8 inches of water, which reduced the pressure 10 lbs. per square inch, from 25 lbs. to 15 lbs.; but the injector throwing in the same quantity of water reduced the pressure only 5 lbs. per square inch, from 25 lbs to 20 lbs. The donkey pump was perhaps not the best means of applying the power, since the steam was all thrown into the atmosphere and its heat lost; but with the injector all the heat of the steam was returned into the boiler.

Mr. C. W. Siemens had made some calculations as to the rise of temperature in the feed water by its passage through the injector, on the assumption that the steam simply carried the water along with it by impact, taking no account of the friction of the water; that is that if 1 lb. of steam in motion were mixed with 2 lbs. of water at rest, the result produced would be 3 lbs. put in motion at 1–3rd the original velocity of the steam. Now since the velocity of water or steam issuing into the atmosphere from the same boiler was equal to that acquired by a falling body in falling through the height of a column of the same water or steam giving the same effective pressure, and since the velocity acquired by a falling body was proportional to the square root of the height through which it fell, it followed that the velocity of the water and of the steam would be proportional to the square roots of their relative volumes; and as the volume of steam with 1 atmosphere effective pressure was 860 times that of water, it would issue with $\sqrt{860}$ or 29 times the velocity of the water from the same boiler. Hence the steam issuing would just balance 29 times its own weight of water trying to issue from the boiler; and therefore, assuming the total heat of steam to be 1200° and the original temperature of the feed 100°, the rise of temperature of the feed would be $\frac{1200 - 100}{29 + 1} = 37°$. And calculating the rise of temperature in the same way for higher pressures of steam, there would be

with 1 atmosphere effective pressure	37° rise of temperature.
2	44°
3	50°
4	55°
10	80°

Comparing these theoretical results with the experiments given in Table V, it appeared that in practice with steam of 51 lbs. or about 3 atmospheres effective pressure the rise of temperature was 74°, while the calculation gave only a little more than 50°: but then it had been assumed that there was no loss of power by friction, and the quantity of feed water propelled into the boiler had been supposed to be the maximum amount theoretically possible. The calculation accordingly gave the minimum rise of temperature when the steam

was only just able to balance the pressure of the water tending to escape from the boiler; and consequently in practice the actual rise of temperature must always be greater than that obtained by the calculation; but the two results differed not more he thought than might be expected, if all losses of effect were taken into account. The table agreed, moreover, with the calculation in giving a greater rise of temperature at higher pressures of steam, although the losses of effect must necessarily increase with the pressure or rather with the increase of velocity of the jet. Much must also depend upon the proper adjustment of the instrument to make the quantity of water injected a maximum.

The Chairman had made some experiments with a No. 8 injector on a stationary boiler and had tried it under the opposite extreme to that assumed in Mr. Siemens' calculation, injecting the least possible quantity of water into the boiler, in order to ascertain the least quantity of water that the injector would work with. In one experiment with 50 lbs. steam injecting 6 gallons per minute, the temperature of feed was 50° and the delivery 190°, showing as much as 140° rise of temperature acquired in the injector; and with 55 lbs. steam injecting 10 gallons per minute, the feed was 105° and the delivery 208°, giving 103° rise of temperature. He had also tried varying the admission of steam through the extreme range allowed in the instrument, keeping the supply of feed water uniform, and found there was only 5° variation in the rise of temperature, the total rise of temperature varying only from 140° to 145°. With 48 lbs. steam and a delivery of 14 gallons per minute, the maximum quantity of water that the injector could deliver at that pressure, the rise of temperature was 110°.

Mr. Robinson said he was much astonished in trying the experiments given in the paper to find that the rise of temperature produced in the water in passing through the injector did not increase as had been expected with increased pressures of steam; but this might be partly accounted for by the consideration that at a higher pressure the steam issued at a greater absolute velocity and was therefore not in contact with the water so long, so that there was less time for condensation and more feed water required for effecting it, and

consequently the rise of temperature was scarcely increased perceptibly. These experiments gave the maximum delivery of the injector that could be obtained in practice at different pressures of steam, and therefore showed the minimum rise of temperature in the water delivered; whereas in the experiments mentioned by the Chairman the proportion of water to steam had been much less, and the rise of temperature obtained was consequently greater. The injector gave facility for a great range of action by varying the proportion of water and steam, as shown in Table VII, where the quantity of water delivered was varied about 55 per cent. of the maximum delivery; and the extent of this range increased with the pressure of steam.

Mr. E. A. Cowper asked whether any experiments had been made to try whether air was drawn into the injector by the velocity of the current of water, or whether the admission of air was in any way necessary to the working of the instrument, as this would be a fatal objection in the case of condensing engines working with a high degree of vacuum.

Mr. Robinson said he had tried holding very light substances near the stream of water, and there was not any draught of air towards it; and the injector worked just the same when the sight holes were closed up air-tight and the end of the overflow pipe submerged under water, so that no air passed in with the water, showing that no air was necessary to its working. In starting the injector to work it was necessary first to make a vacuum in the feed water chamber, in order to raise the feed, and any air in the instrument was then expelled by the overflow before beginning to work.

Mr. E. A. Cowper said he had made a calculation as to the useful effect of the injector when employed in forcing water, reckoning only the quantity of water delivered as given in the experiments and taking no account of the rise of temperature produced, and found that the duty amounted to only about 8 per cent. This of course did not represent the useful effect obtained when the injector was employed in feeding a boiler, for all the heat imparted to the water then went to diminish the consumption of fuel; but this heat would be lost if the injector were applied simply to raising water. For calculating the actual power of the instrument the quantity of steam expended in working it

should be ascertained by taking the steam from an isolated boiler in which the consumption of fuel and quantity of steam supplied could be accurately measured, in order to learn what proportion of the heat was absorbed as power; if this were ascertained it would afford an opportunity of testing the theory of the conversion of heat into mechanical effect. He supposed the injector had not been tried with a jet of air instead of steam.

Mr. ROBINSON observed that M. Giffard had used the plan of a conical water pipe having a conical steam pipe within it, as employed in the injector, for the purpose of raising water; and this method was available as a simple direct application of steam power, where fuel was not a consideration, though it would of course be far from economical of power. With a jet of air the injector would only draw water and not force it, as forcing could be done only when the power was exerted by a fluid that could be condensed so as to become non-elastic before passing the throat of the delivery pipe. He had tried an experiment of raising the feed water tank to a higher level than the injector, in order to ascertain whether a higher temperature of feed would then be admissible; but there was not found to be any advantage in this respect, for the temperature of feed was obliged to be kept down within a certain limit, in order to condense the steam completely, and when the temperature approached 140° the injector would stop working with 50 lbs. or 60 lbs. steam. He recommended as a general rule placing the tank about 1 foot higher than the feed water chamber of the injector, which would save the trouble of having to make a vacuum on first starting.

Mr. W. F. BATHO said they had had a No. 4 injector working for about four months on a stationary boiler at the Bordesley Works, Birmingham, and the feed water tank was 10 feet above the injector; the pressure of steam was from 30 lbs. to 40 lbs., and the injector had worked with the feed at as high a temperature as 159°, which was no doubt owing to the head of feed water above the injector. The only difficulty that he had noticed on reaching a high temperature of feed was that the check valve in the bottom delivery pipe was apt to get into a state of vibration and not shut fairly, and then the water escaped out of the boiler.

Mr. Robinson said he had noticed the same occurrence and believed it arose from the valve being made to dance in its seat, in consequence of the steam not being properly condensed in the delivery pipe, and a lower temperature of feed or a smaller quantity of steam was then required. The bottom valve might be taken away entirely or put further away from the injector; in many recently made it had been removed, and an ordinary stop valve substituted next the boiler.

The Chairman proposed a vote of thanks to Mr. Robinson for his paper, which was passed.

The following paper was then read:—

ON PINEL'S MAGNETIC WATER GAUGE FOR STEAM BOILERS.

By Mr. GEORGE PIGGOTT, of Birmingham.

Most appliances for indicating the height of water in steam boilers are liable to be inefficient for the purpose, chiefly from undue friction caused by the buoy rod passing through a stuffing box or packed joint: the packing is often so tight that the float will not move the rod; and if it is packed lightly to dispense with the friction, then there is a leakage of steam which is very objectionable. The Magnetic Water Gauge described in the present paper, the invention of M. Pinel of Rouen, is free from these objections: the chief points to be noticed are, its compactness and simplicity, and the facility of fixing, its exactness in working, and durability, and the very little attention required to keep it in working order.

The gauge is shown in Figs. 1, 2, and 3, Plate 15, and consists of an upright cast iron pipe A, on the top of which is fixed a brass box B square in section, as shown in the plan, Fig. 3. A hollow cylindrical float C proved to stand a pressure of 10 atmospheres is attached to an iron rod D, passing through the bush E without any packing, and also through the guide F, perfectly easy and free. To the upper end of this rod is fixed a strong horse-shoe magnet G, shown enlarged in Figs. 4 and 5, the poles being bent forwards at right angles to the body of the magnet, which falls or rises in the brass box B with the fall or rise of water in the boiler. On the exterior face of the box is an isolated iron needle, held merely by the attraction of the poles of the magnet, which it follows in all its movements, rolling on the face of the box as the magnet rises or falls according to the height of water in the boiler. The face of the box is silvered and graduated, so that the least movement of the needle is perceptible: it is covered with glass to protect it from dust and injury. On the side of the upright

pipe A a shrill whistle H is fixed, closed by a valve kept shut by the internal pressure of steam: when the float is nearly at the lowest limit of its range, a small stud I on the rod D presses on a lever which immediately opens the valve and allows the steam to sound the whistle; this at once makes known the want of water.

The fixing of the gauge is exceedingly simple, and does not allow any leakage of steam, which is not only a waste but often injures the plates of a boiler. A hole about $1\frac{1}{4}$ inch diameter is drilled in the top of the boiler at the required place, and the gauge is fixed upright, the joint being made with india-rubber and a nut screwed on inside the boiler. The length of the buoy rod is adjusted to suit the height of water it is usual to work at, the float being weighted to sink just half way in the water, so that the adjustment is reduced to a mere matter of measurement; the needle points to zero when the water is at its proper working height, and the water level may then be lowered $2\frac{1}{2}$ inches before the whistle sounds; but if it exceeds this limit by $\frac{1}{8}$ inch, the whistle will sound the alarm, and will continue to whistle till the water level is raised again. The gauge is sometimes constructed with two whistles, for high and low water. The buoy rod is limited in its motion both upwards and downwards: when the water is raised 6 inches above the proper working height, the coupling of the buoy rod comes in contact with the bush E, which prevents the magnet from being forced against the top of the gauge; and when the water falls more than 3 inches below its proper level, the brass coupling which joins the magnet to the buoy rod rests on the top of the guide F, holding the buoy suspended till the water is raised high enough to float it again: this prevents the magnet from moving out of the brass box. Neither of these cases ought to occur, but the provision is made in case of their occurrence. The brass box is planed on the back and front, and for a portion of the width on each side, forming a guide for the magnet to slide in. On the back of the magnet is fixed a brass bar, bearing only on the planed surface on each side of the box, by which the magnet is made to slide perpendicularly; immediately under this bar a light spring is fixed to the back of the magnet, also bearing only on the back of the box, which keeps the poles of the magnet slightly pressing against the face.

This water gauge indicates the height of water so exactly and the absence of friction renders it so sensitive that the writer has noticed, when it has been put just over the fireplace of a double-flue boiler with brisk fires going, that the needle rises and falls with the fluctuation of the water caused by the quick ebullition. The gauge requires scarcely any attention, and the inconvenience of constantly greasing and watching that the float acts is entirely done away with. The silvered face is kept clean by washing with soap and water two or three times a year; this is all the attention it requires.

The total number of these gauges now at work is 3500, 65 of which are in England and the remainder principally in France; all of which are working with as much accuracy as when first put up, and some of them have now been nine years at work. The rubbing of the magnet against the brass box gives it a polish that renders the wear inappreciable: its magnetic power must necessarily be weakened in time from the effects of rust, and it would then require renewal, but at present its durability has not been impaired in any way. As there is no passage of steam through the gauge, the interior is not liable to any incrustation of deposit. Magnetic gauges were put up at the Paris mint in 1855, and have never been touched since that time: they have also been adopted extensively in the French government workshops and in manufactories.

A specimen of the gauge was exhibited, taken to pieces to show the construction.

Mr. W. F. Batho had had three of the gauges at work at a pressure of 30 lbs. to 40 lbs., the longest for 8 months; no injury had occurred to them, and they continued in good working order. The only danger that could arise would be from the magnet becoming corroded by long exposure to the steam, and in one of the gauges that had been taken down recently and taken to pieces to be examined there was a slight indication of corrosion commencing on the magnet.

Mr. J. Robinson asked on what part of the magnet the corrosion took place.

Mr. W. F. Batho said it was on the top of the magnet, where there would always be a little moisture lying from condensation of steam within the gauge.

Mr. C. W. Siemens enquired whether there was found to be any deposit within the gauge, to show that water had been carried up into it.

Mr. W. F. Batho replied that there was nothing but a little moisture from the condensed steam; and the whistle on the gauge showed that it was always full of steam, because the steam sounded it as soon as opened.

Mr. J. B. Neilson thought the magnetic water gauge would be very useful, especially for boilers with internal flues where it was so particularly important to know the water level correctly. He thought the hollow float exhibited appeared rather light for working the gauge, and that a stone float would be preferable as safer and more durable, if it could be arranged to be counterpoised. He enquired what was the cost of the gauge.

Mr. W. F. Batho replied that the gauge cost £7 10*s.* or £7 15*s.*

Mr. J. Robinson observed that there was no stuffing box for the float rod in this gauge, and therefore no friction to be overcome by the float, so that a light float was quite sufficient to work the rod.

Mr. W. Richardson had used a different construction of magnetic water gauge on a boiler working up to 50 lbs. pressure situated in a forge, where he was afraid of a glass gauge being exposed to injury, and wanted a gauge that would not be too high up to be easily seen. It consisted of a copper float about 7 inches diameter fixed on a lever, the horizontal spindle of which passed freely through the front of the boiler into the casing of the gauge without any stuffing box or packing, and carried at its outer extremity a bar magnet fixed at right angles to the spindle and parallel to the float lever, working within the casing of the gauge: outside the casing was a steel indicating finger, working loosely on a pin in the same centre line as the spindle of the magnet, which showed the height of water on a dial plate. The magnet and indicating finger both rotated on the centre point of their length, so that both were completely balanced and the finger was propelled by each end of the magnet. This gauge had now been at work for 18 months and continued perfectly correct;

when first put up, immediately over the fire, its sensitiveness was so great from the violent ebullition that the index was very unsteady, and in order to keep the surface of the water quiet a piece of sheet iron had to be fixed horizontally inside the boiler, sufficiently below the surface of the water not to interfere with the range of the float.

Mr. C. W. Siemens had seen a magnetic water gauge brought over from America about fifteen years ago, similar to the gauge just referred to, having a radial needle worked by a magnet attached to the float, but had not seen it put in operation.

Mr. G. F. Muntz observed that there was one advantage in the magnetic gauge described in the paper, that if the magnet ever got out of order and lost its power the needle would drop down to the bottom of the face, and it would become evident that the gauge was not in working order; but in most gauges having a finger, the finger did not drop when the gauge got out of order, but remained pointing to the dial and apparently indicating the water level.

Mr. E. A. Cowper thought the principle of the magnetic gauge was a good one, as it did away with the friction of the stuffing box required in ordinary gauges, which was always liable to be packed too tight and check the action of the gauge. One advantage in the construction of the gauge now shown was that the needle was made with a small ring round it at each end, so as to roll on the face instead of sliding, which made its motion very easy.

Mr. F. J. Bramwell remembered a magnetic gauge being proposed by Du Trembley several years ago, having a magnet working inside a tube with a ring attached to it on the outside, but there would be more friction with a ring than with the rolling needle of the gauge now shown.

Mr. C. May remarked that if a glass tube were fixed on the top of the gauge and could be kept clean, the top of the float rod itself might be seen working within it, and there would be no need of a magnet or an external ring.

A vote of thanks was then passed to Mr. Piggott for his paper.

The meeting then terminated.

Experimental Stove heated by Coal Fire.

Fig. 1. *Vertical Section.*

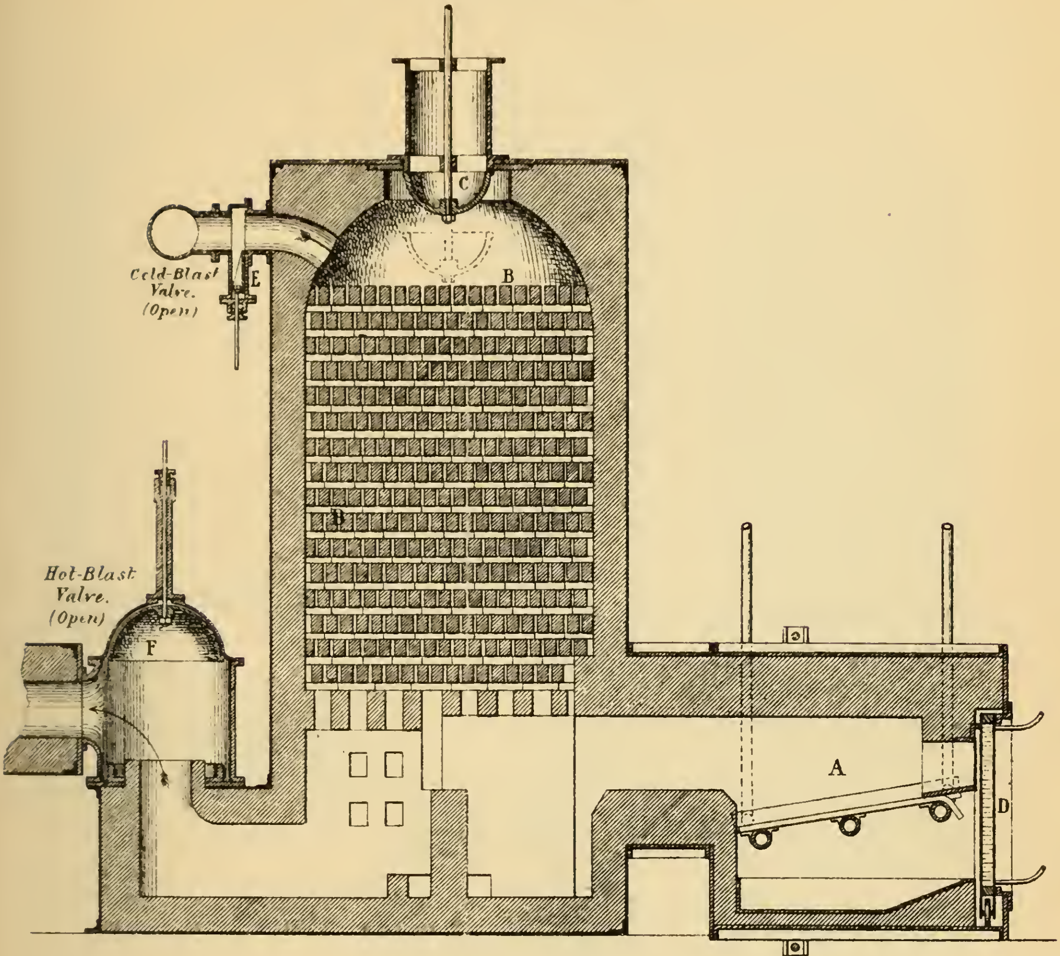
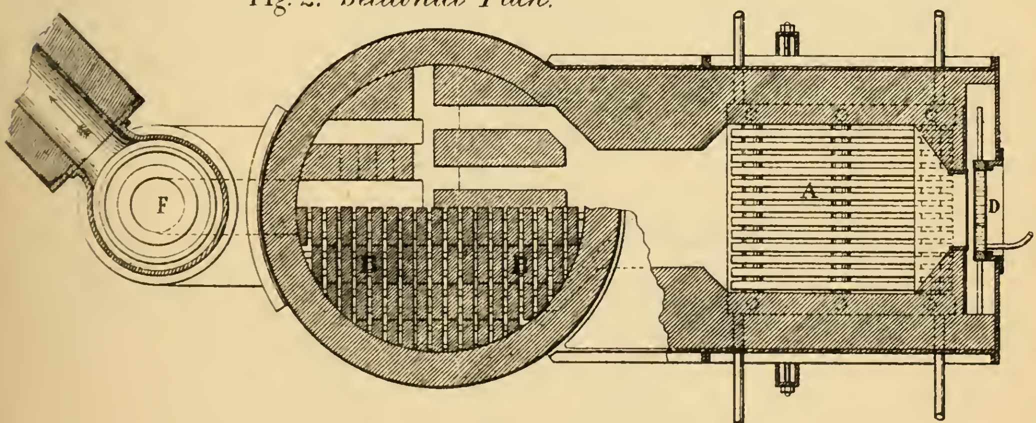


Fig. 2. *Sectional Plan.*



Scale 1/60th.

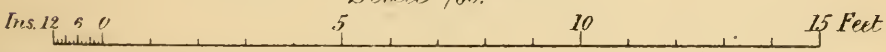


Fig. 3. *Elevation of Gas Store.*

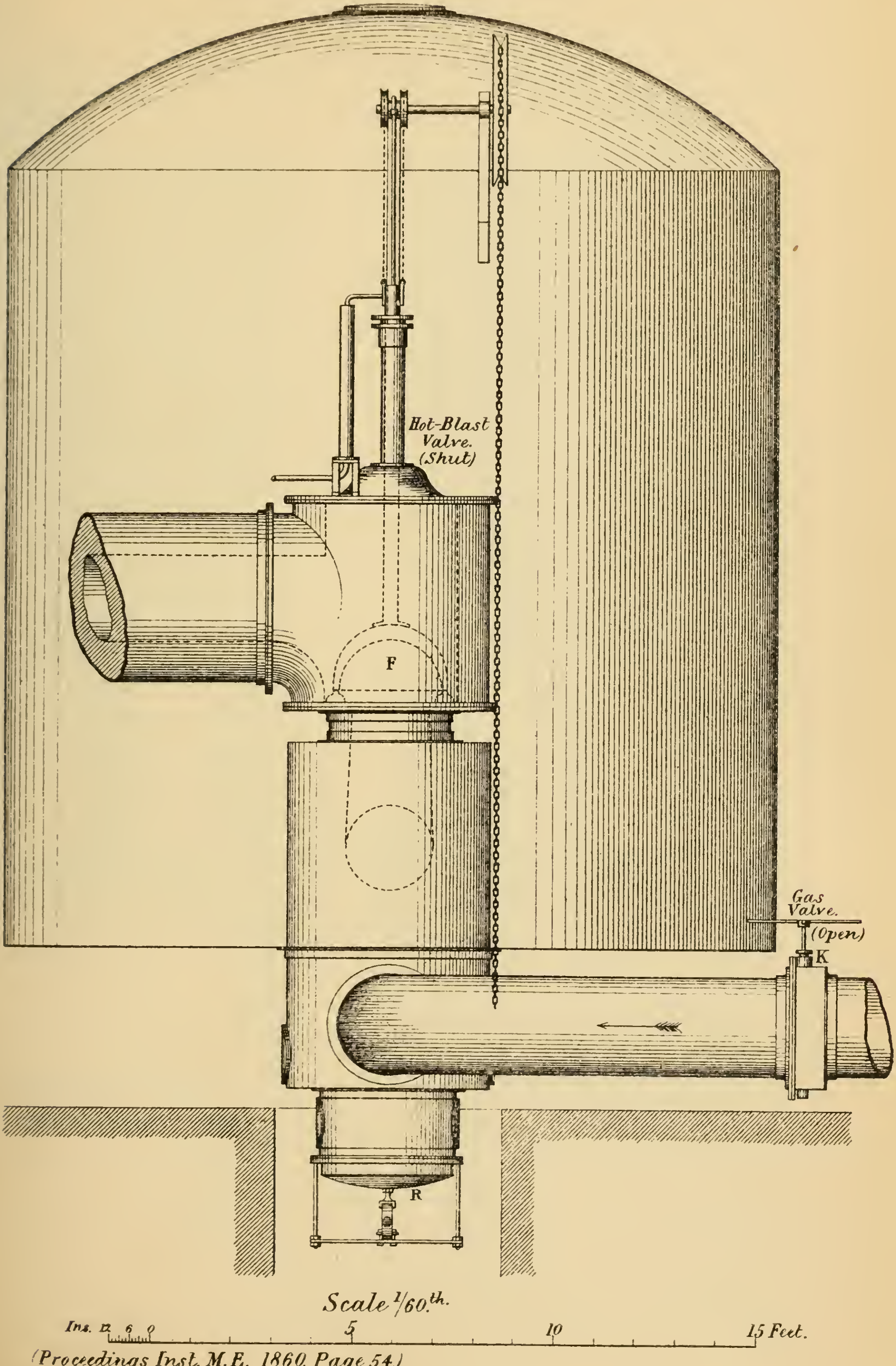
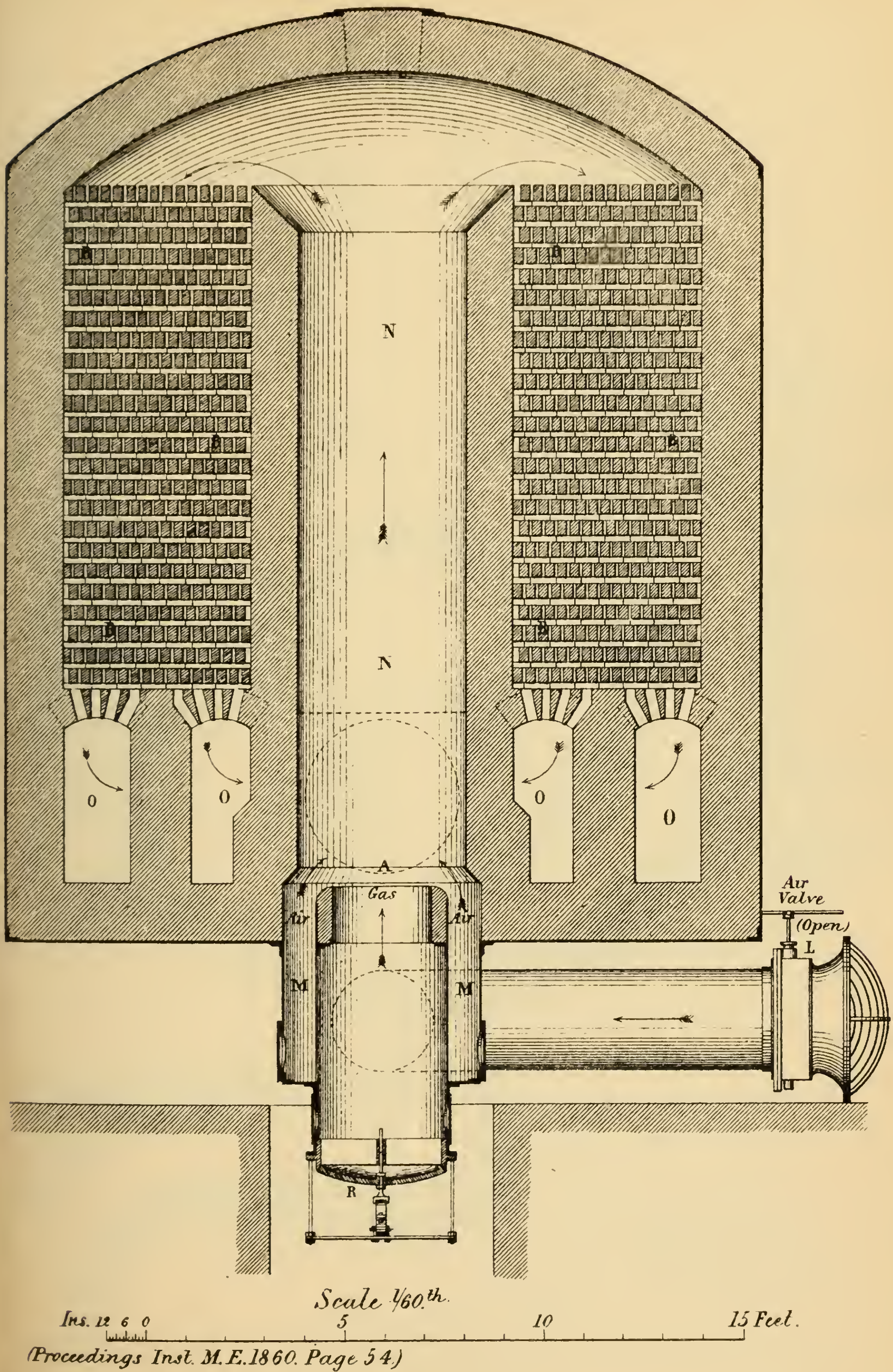


Fig. 4. *Vertical Section of Gas Stove.*



(Proceedings Inst. M.E. 1860. Page 54.)

Fig. 5. *Sectional Plan of Gas Stove.*

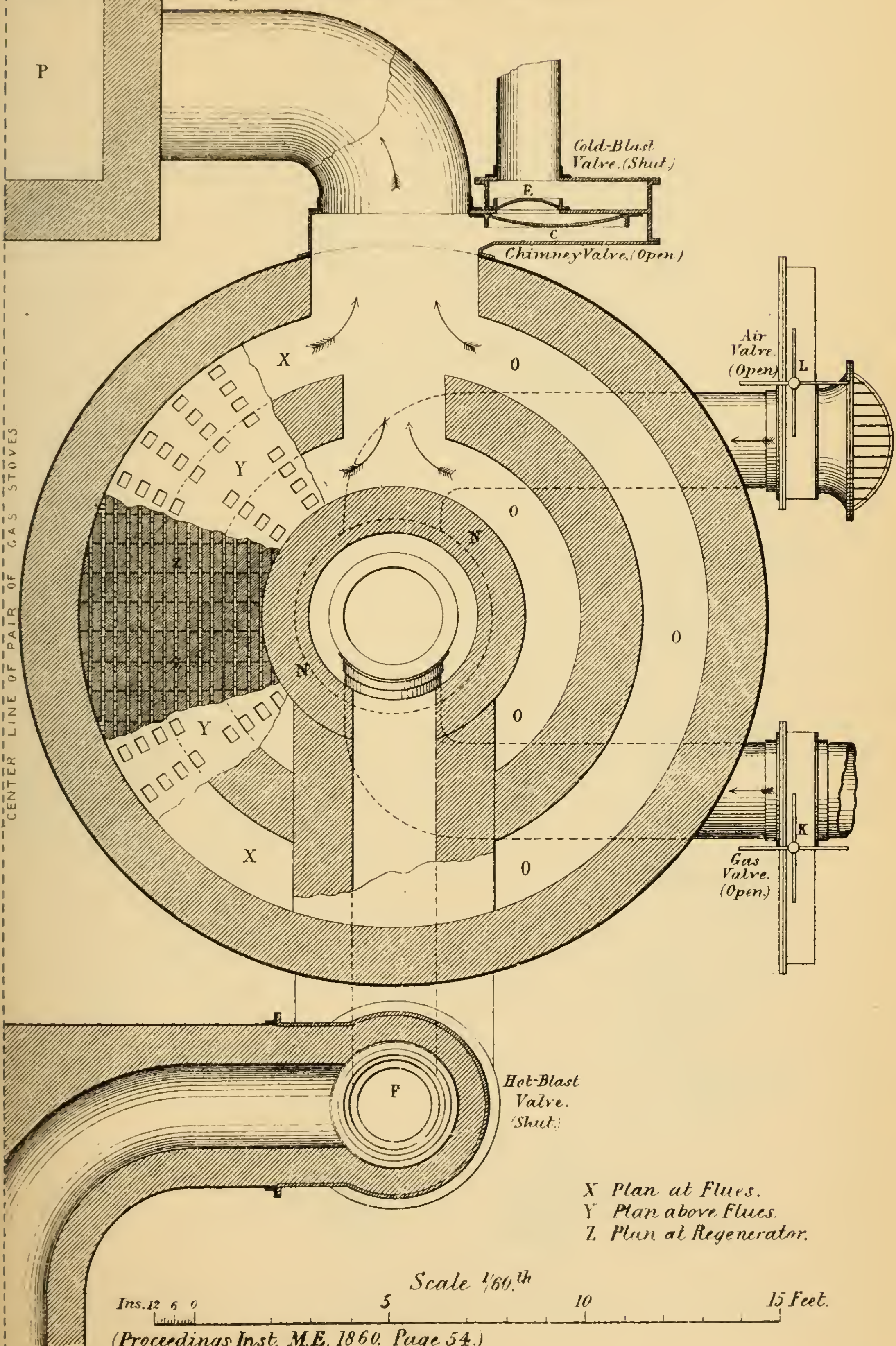


Fig. 6. *Plan of Pair of Experimental Stoves heated by Coal Fires.*

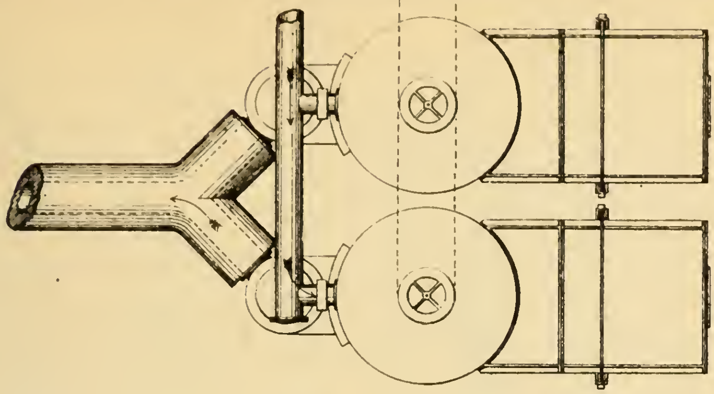
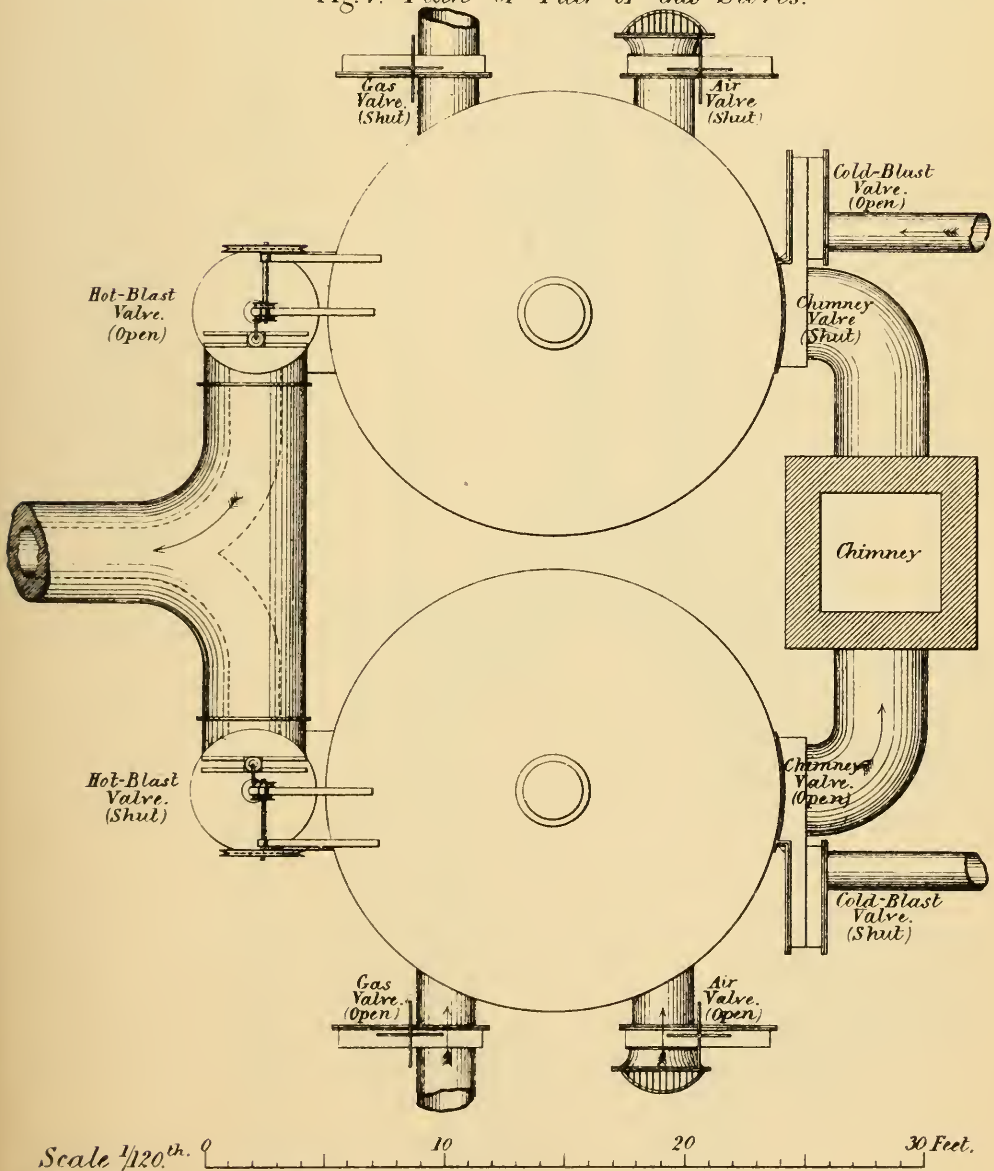


Fig. 7. *Plan of Pair of Gas Stoves.*



(Proceedings Inst. M.E. 1860. Page 54.)

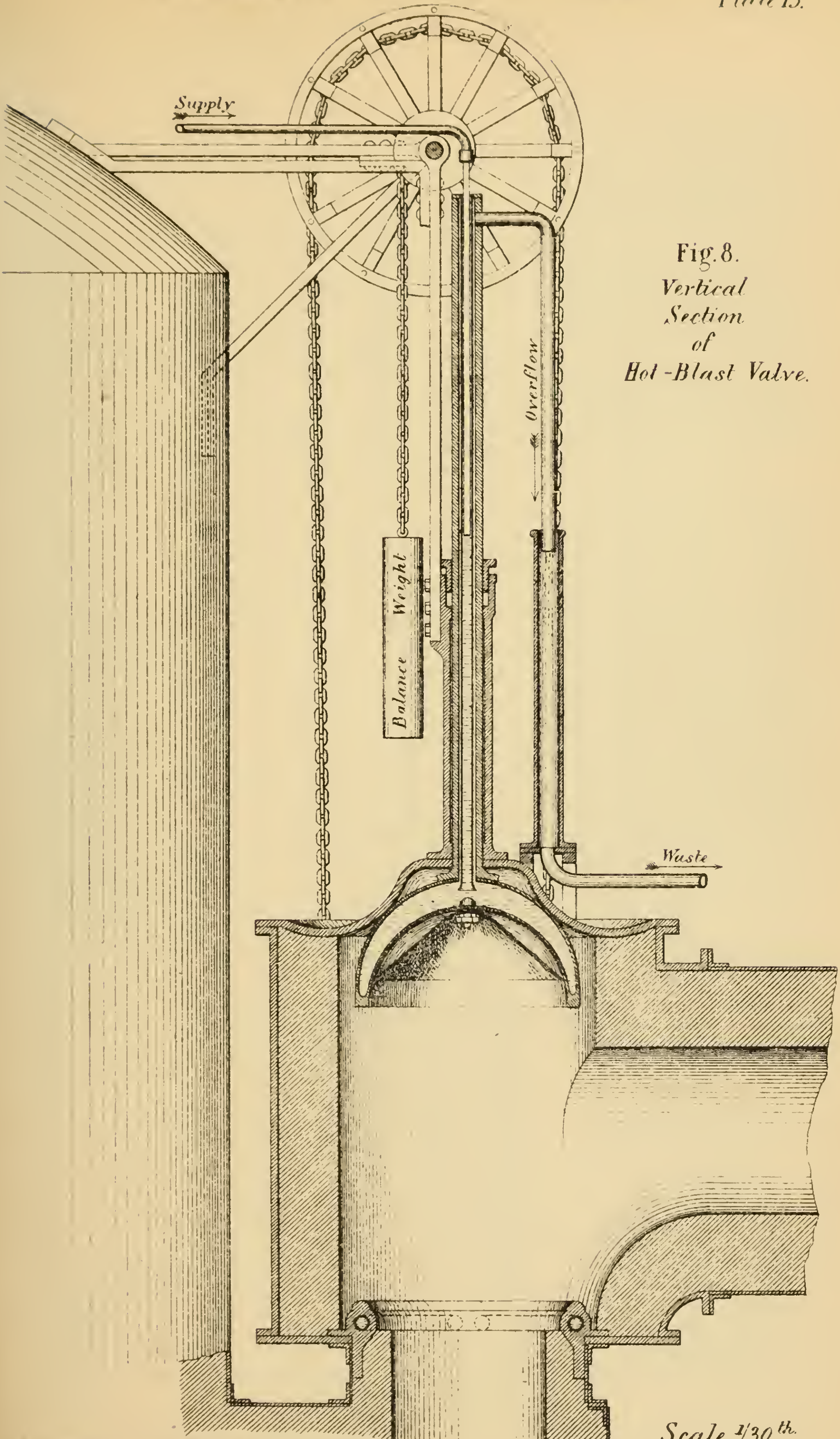
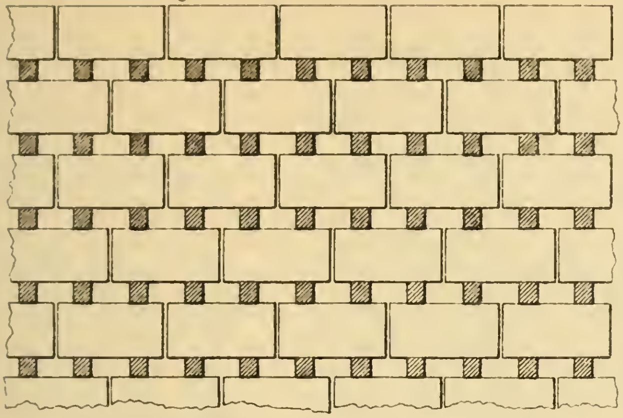


Fig. 8.
Vertical Section of Hot-Blast Valve.

Scale 1/30th.

Arrangement of Firebrick in Regenerator.

Fig. 9. *Longitudinal Section.*



Scale 1/20th. 0 10 20 Inches.

Fig. 10. *Transverse Section.*

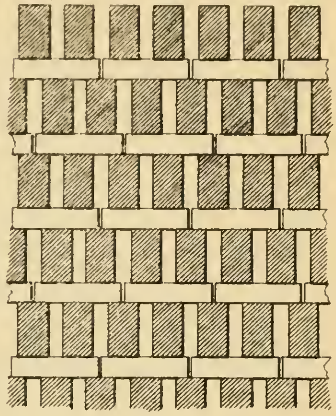


Fig. 11. *Plan.*

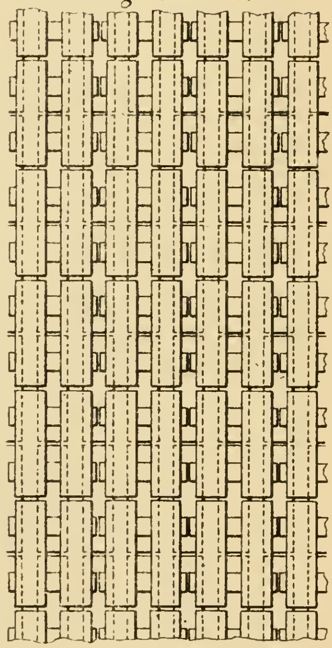


Fig. 12.
Sliding Door of Coal-Fire Stove.
Scale 1/20th.

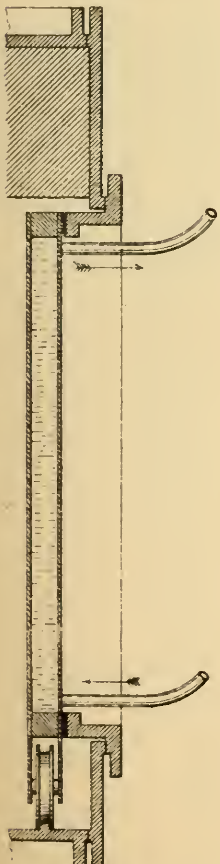


Fig. 13.
Vertical Section of Pyrometer.

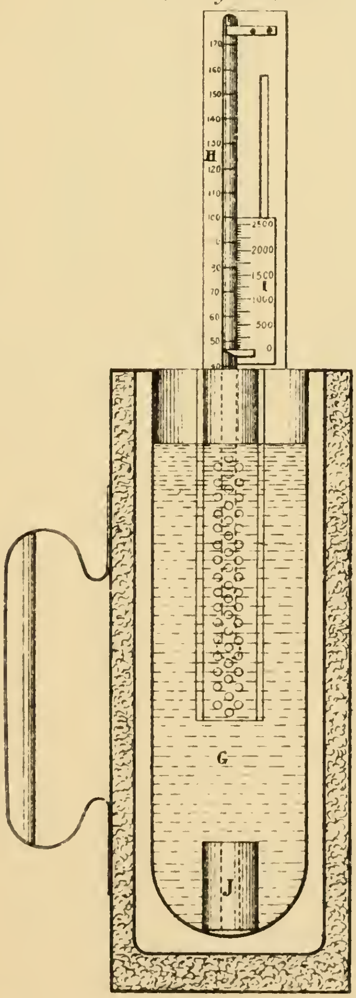
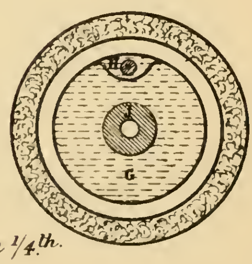
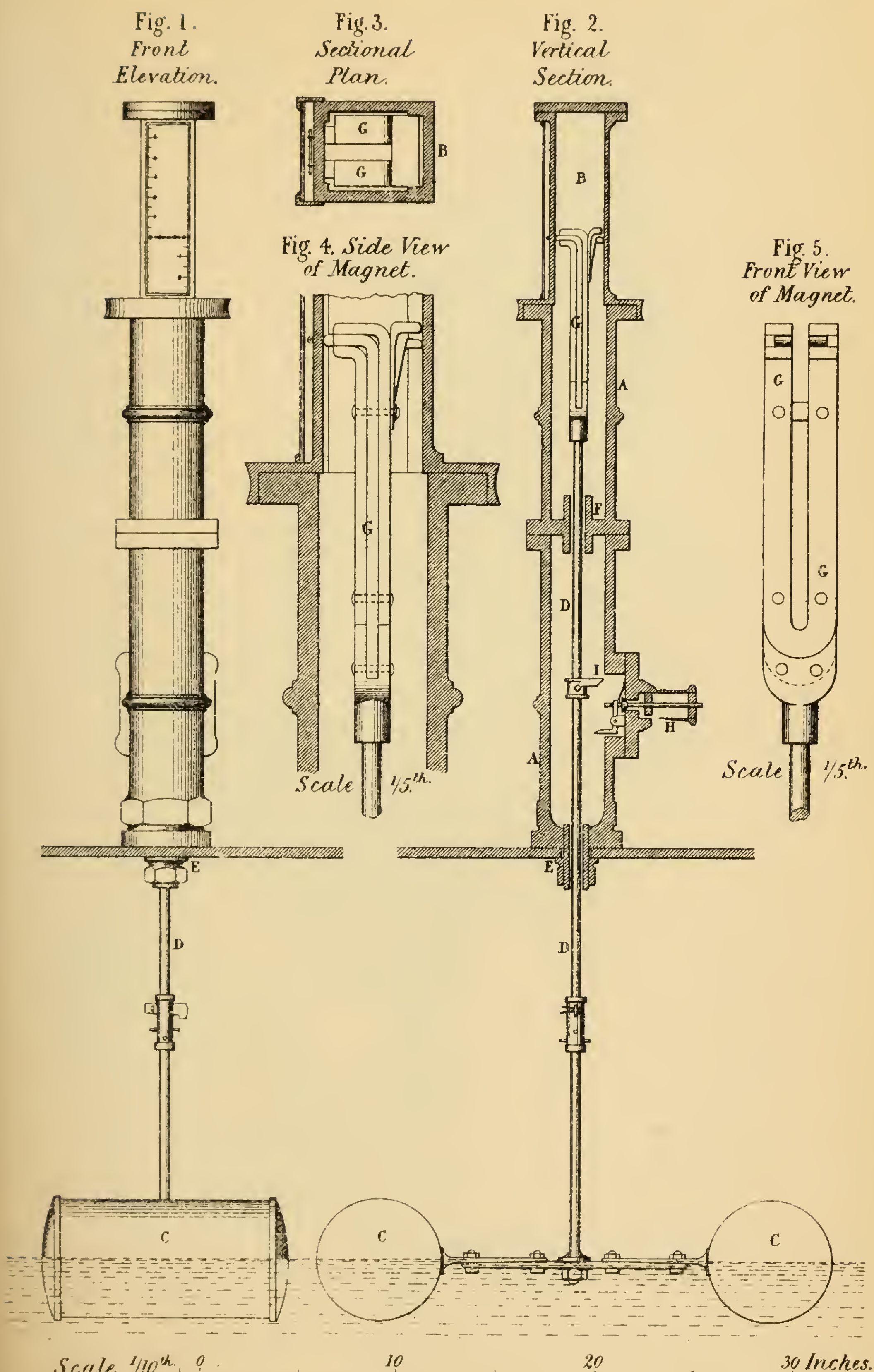


Fig. 14.
Transverse Section of Pyrometer.



Scale 1/4th. 0 1 2 3 4 Ins.

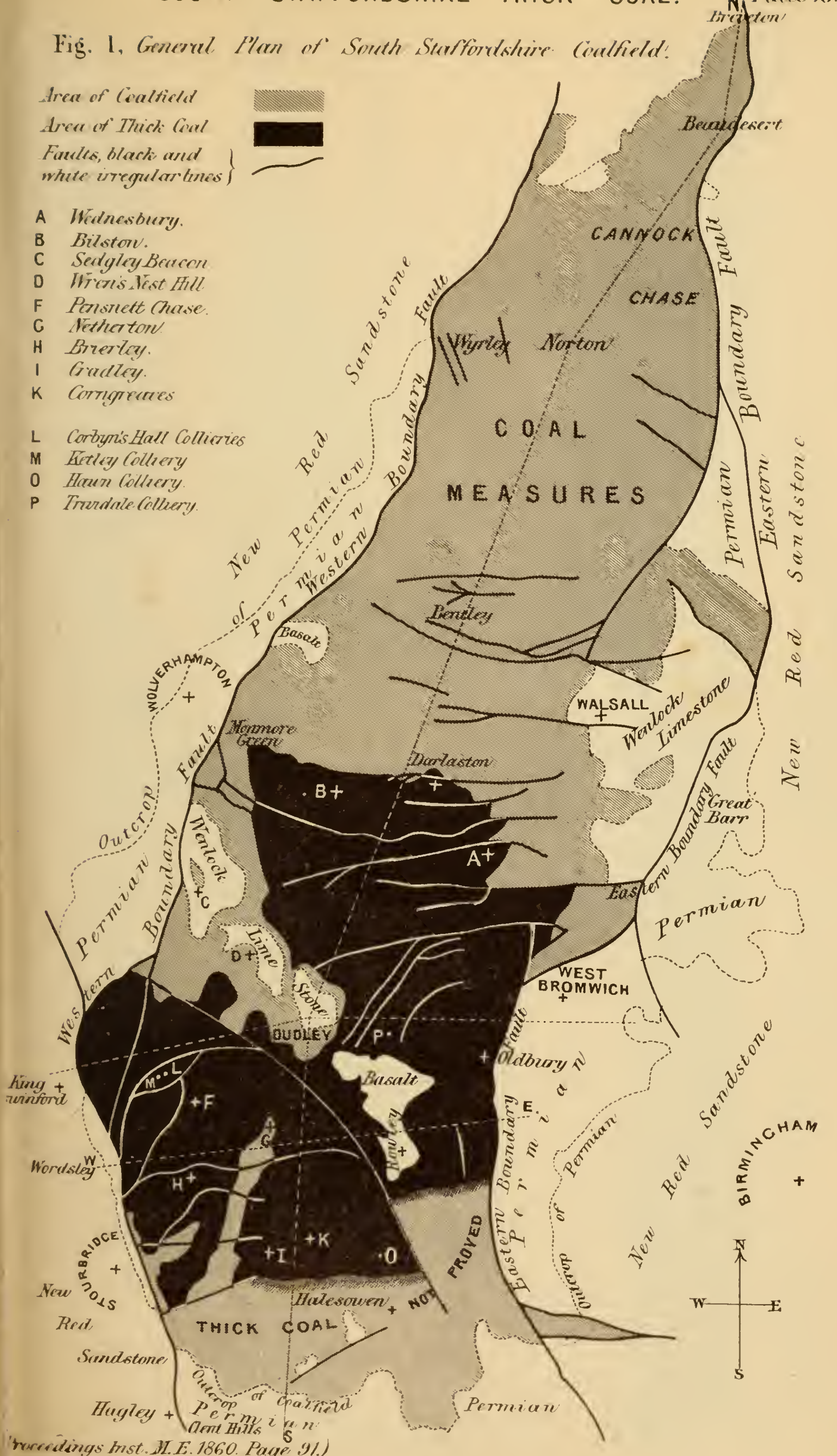
MAGNETIC WATER GAUGE. Plate 15.



(Proceedings Inst. M.E. 1860. Page 83.)

SOUTH STAFFORDSHIRE THICK COAL. *Plate 16.*

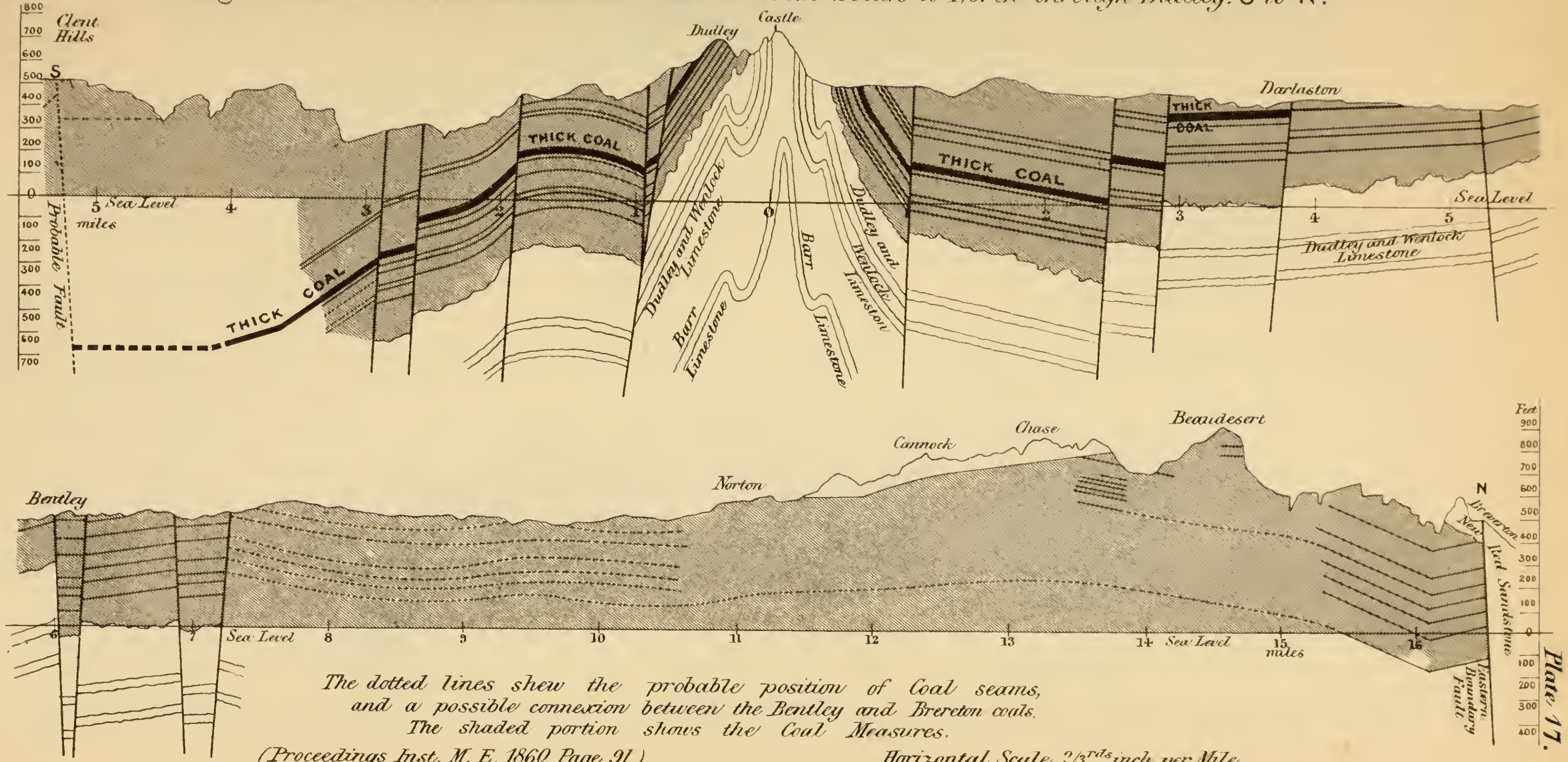
Fig. 1, *General Plan of South Staffordshire Coalfield.*



(Proceedings Inst. M.E. 1860. Page 91.)

SOUTH STAFFORDSHIRE THICK COAL.

Fig. 2. *Section of South Staffordshire Coalfield from South to North through Dudley.* S to N.



The dotted lines shew the probable position of Coal seams, and a possible connexion between the Bentley and Brereton coals. The shaded portion shows the Coal Measures.

(Proceedings Inst. M. E. 1860, Page 91.)

Horizontal Scale 2/3rds inch per Mile.

Plate 17.

SOUTH STAFFORDSHIRE THICK COAL.

Fig. 3. *Section of South Staffordshire Coalfield from West to East through Dudley.*

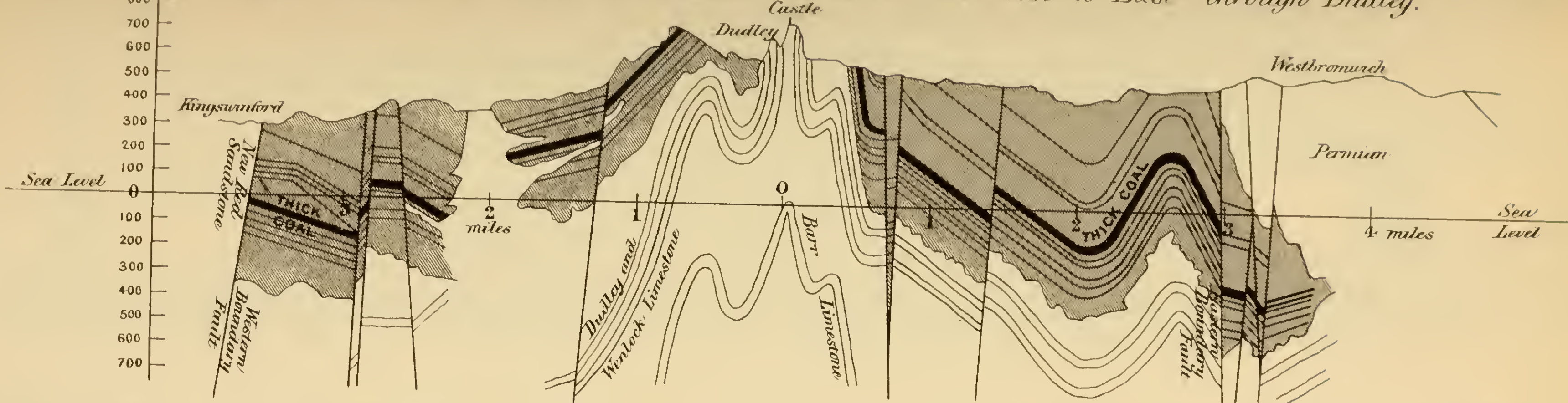
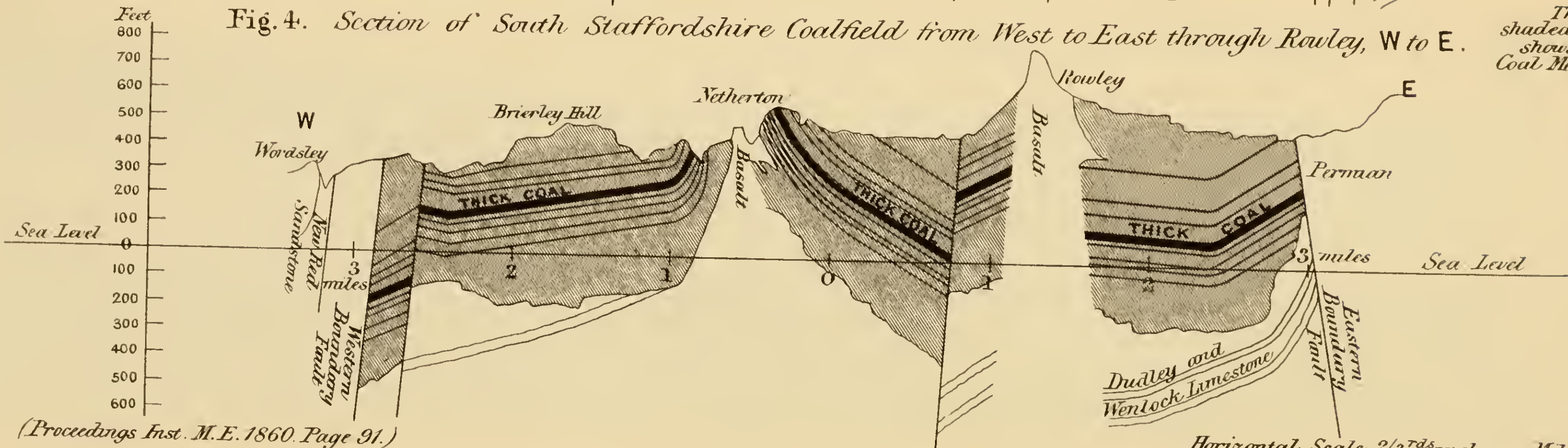


Fig. 4. *Section of South Staffordshire Coalfield from West to East through Rowley,* W to E.

The shaded portion shows the Coal Measures.



(*Proceedings Inst. M.E. 1860. Page 91.*)

Horizontal Scale 2/3rds inch per Mile.

Plate 18.

SOUTH STAFFORDSHIRE THICK COAL.

Fig. 5. *Section of Rib and Pillar System of Working the Thick Coal.*

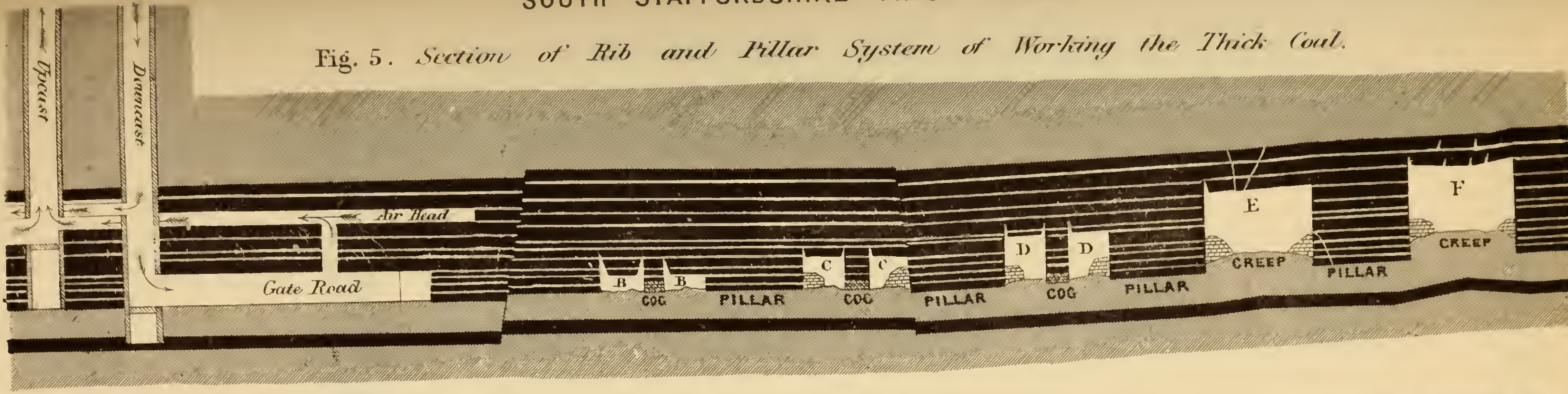


Fig. 6. *Section of Long Wall System of Working the Thick Coal.*

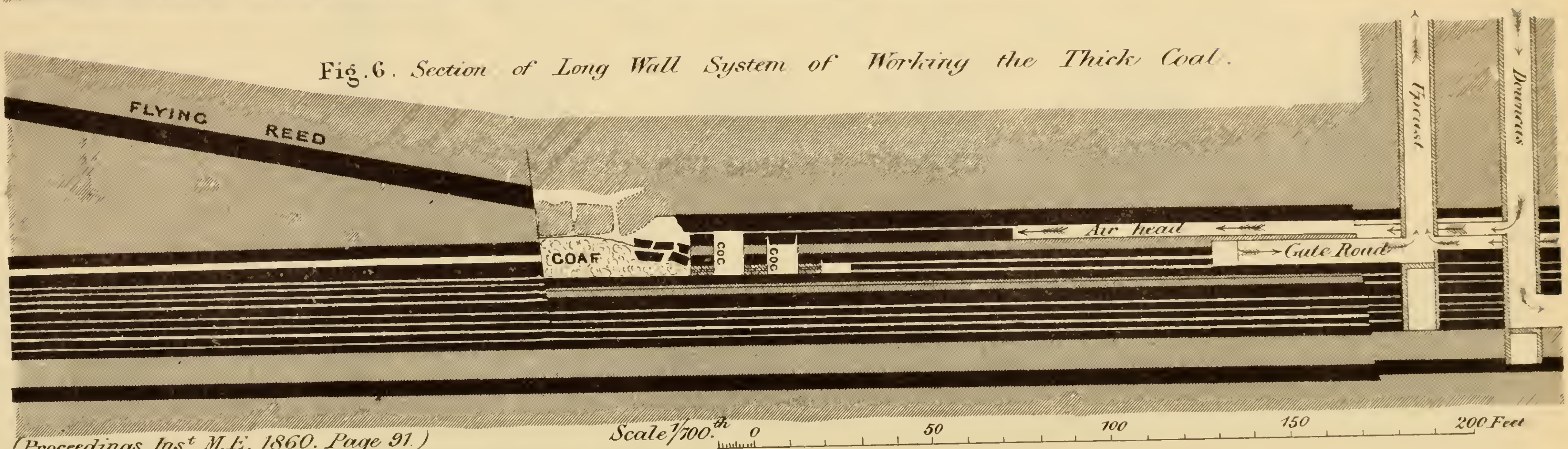
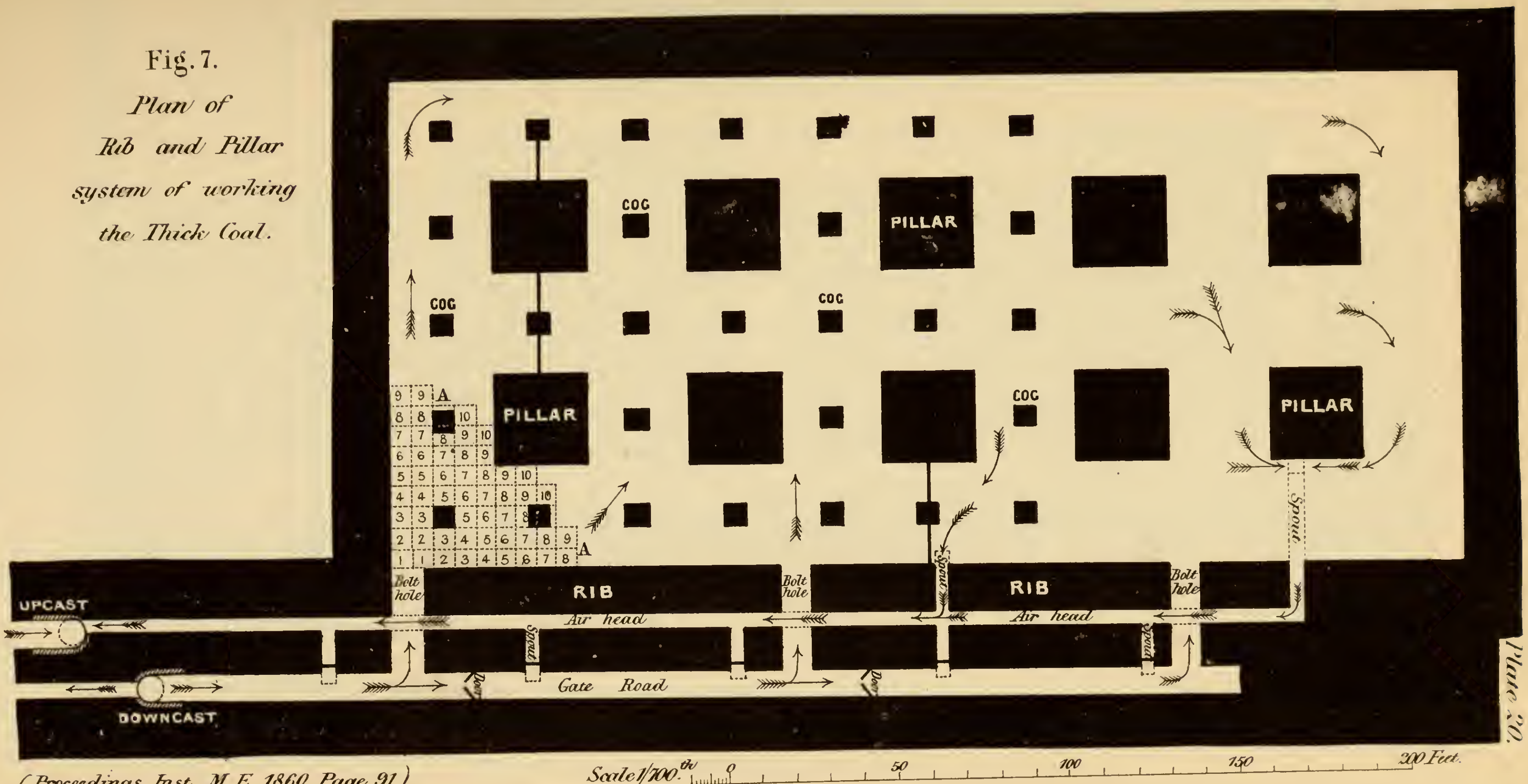


Plate 19.

SOUTH STAFFORDSHIRE THICK COAL.

Fig. 7.

Plan of Rib and Pillar system of working the Thick Coal.

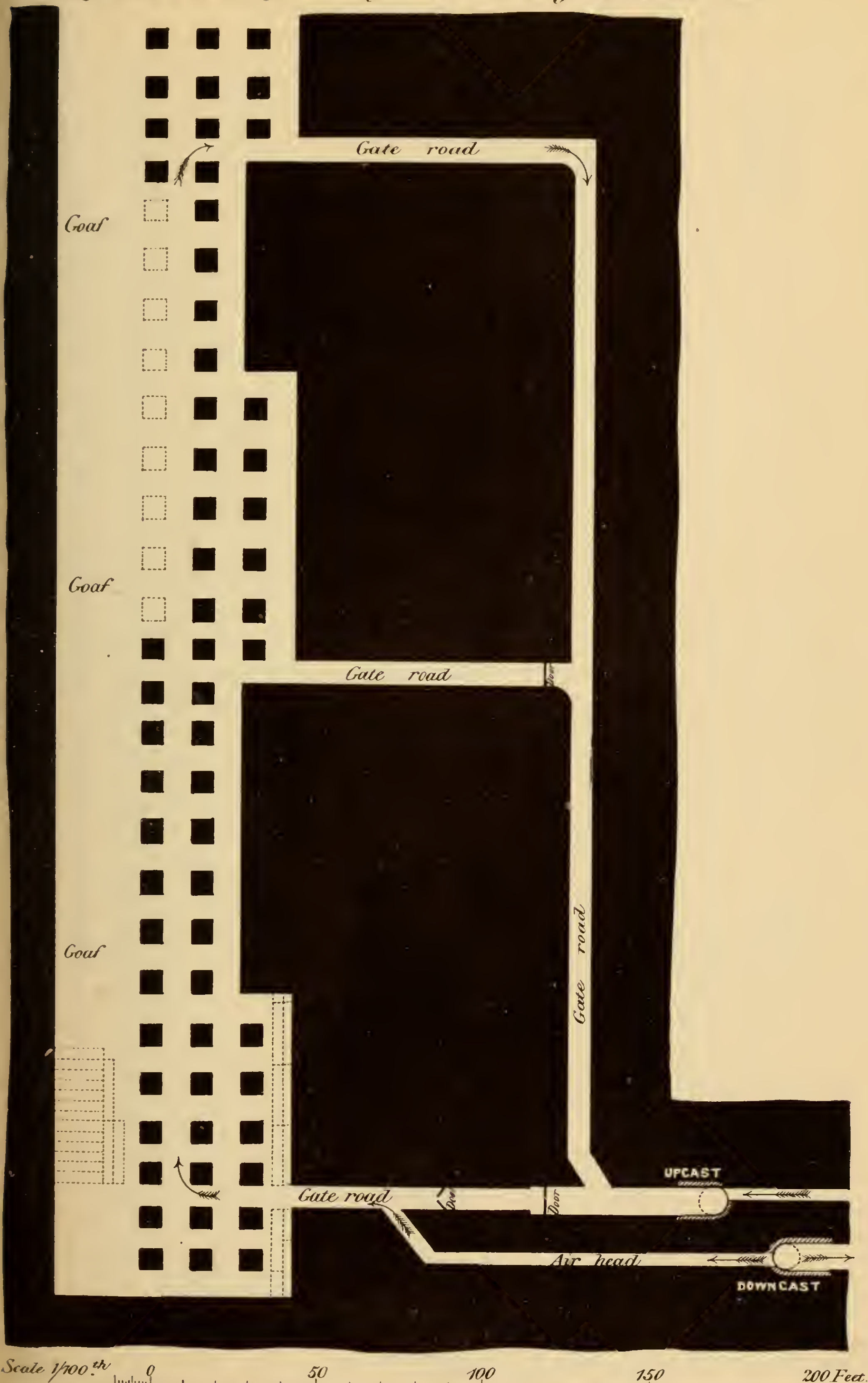


(*Proceedings Inst. M. E. 1860. Page 91.*)

Plate 20.

SOUTH STAFFORDSHIRE THICK COAL. *Plate 21.*

Fig. 8. *Plan of Long Wall system of working the Thick Coal.*



Proceedings Inst. M.E. 1860. Page 91.)

SOUTH STAFFORDSHIRE THICK COAL.

Fig. 9. *Section of Dislocated Position of Thick Coal in Corbyn's Hall Colliery.*

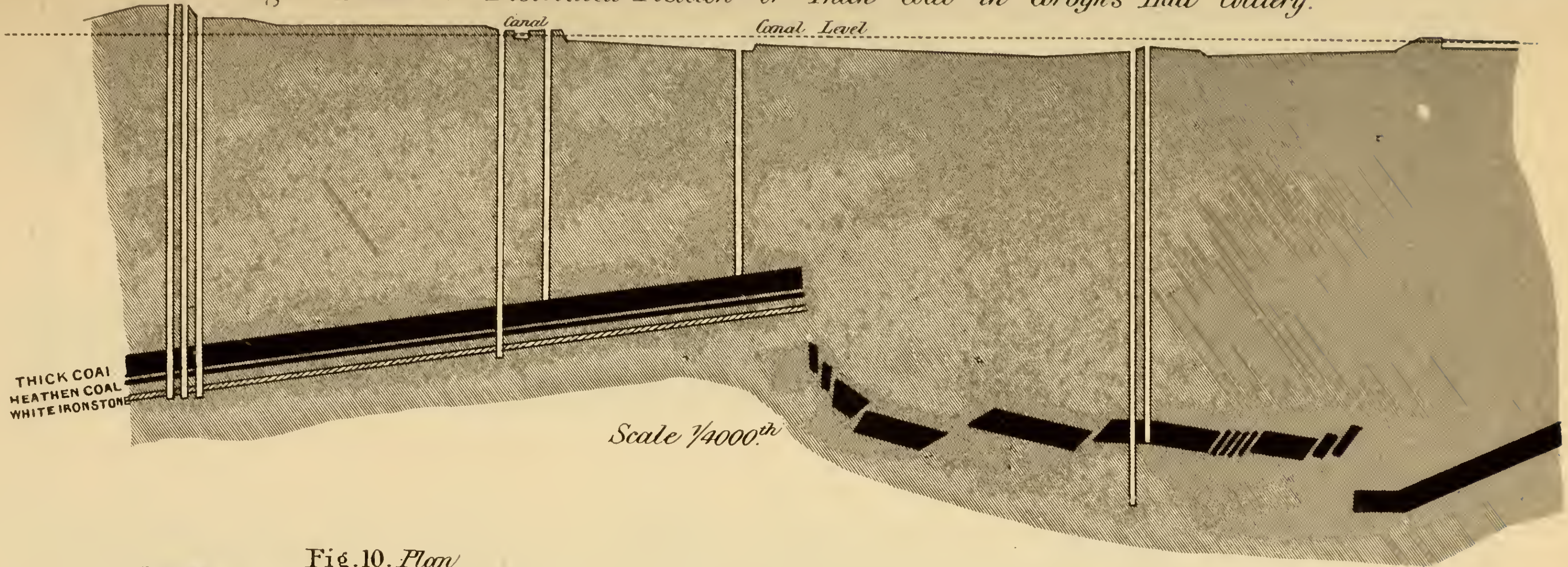


Fig. 10. *Plan*

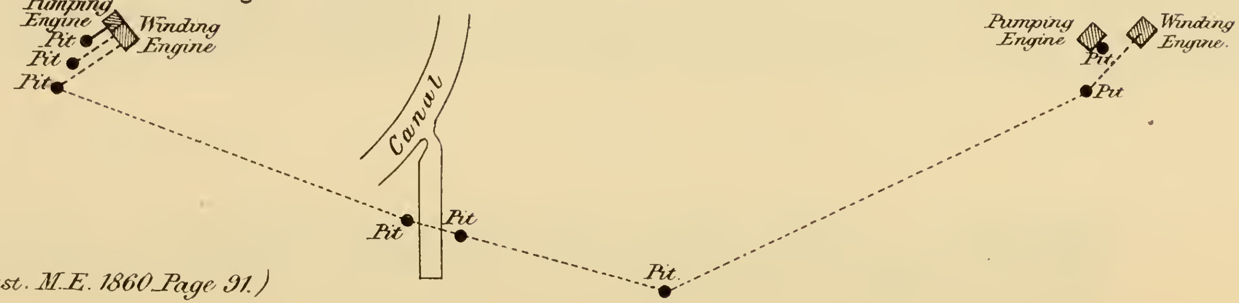


Fig. 11. *Plan of Shaft with Trumpeting*

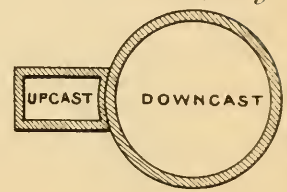


Plate 22.

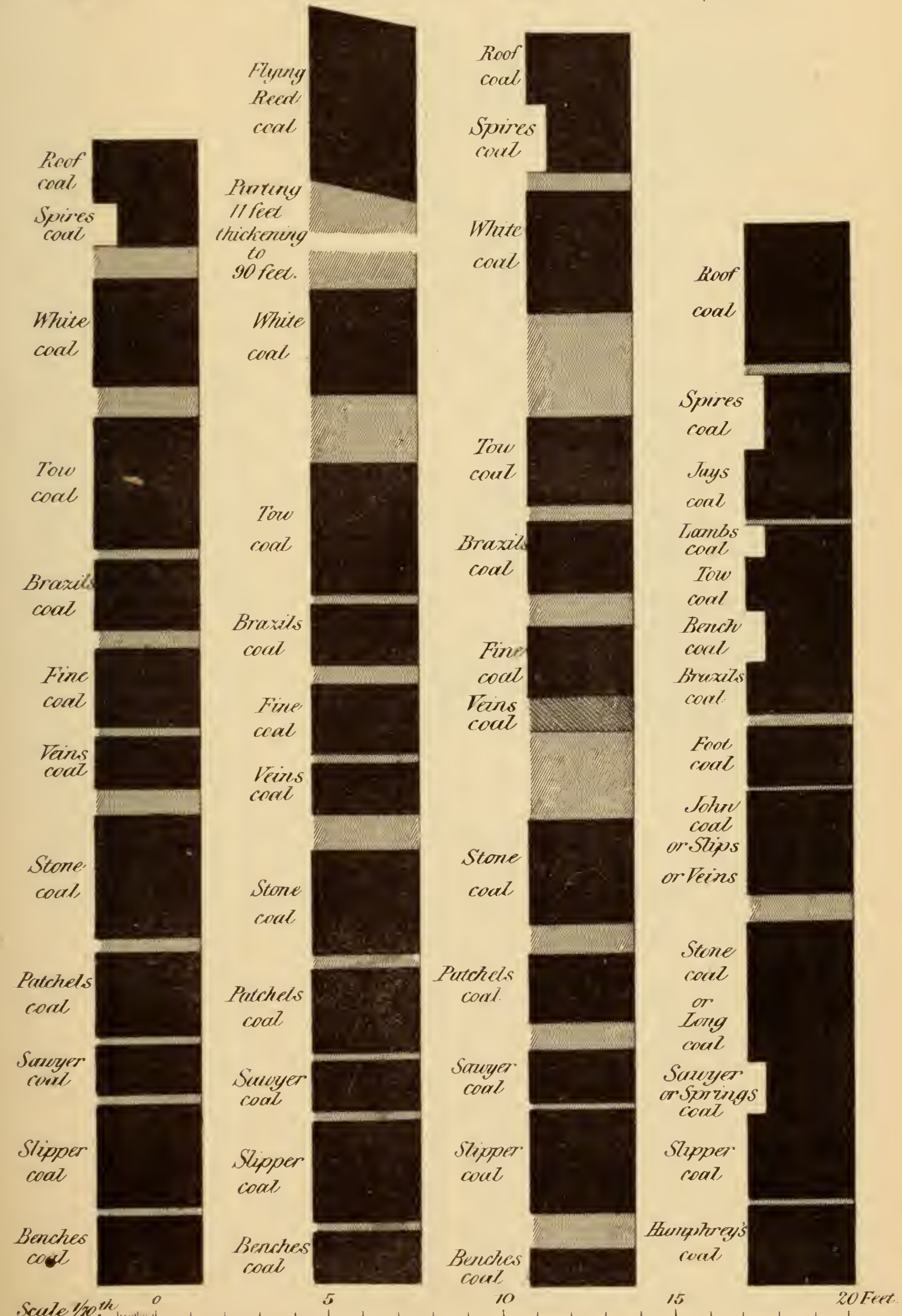
Sections of Thick Coal.

Fig. 12. *Corbyn's Hall Colliery, Kingswinford Western district* (Table I.)

Fig. 13. *Ketley Colliery, Kingswinford. Western district.* (Table II.)

Fig. 14. *Hawn Colliery, Halesowen Western district.* (Table III.)

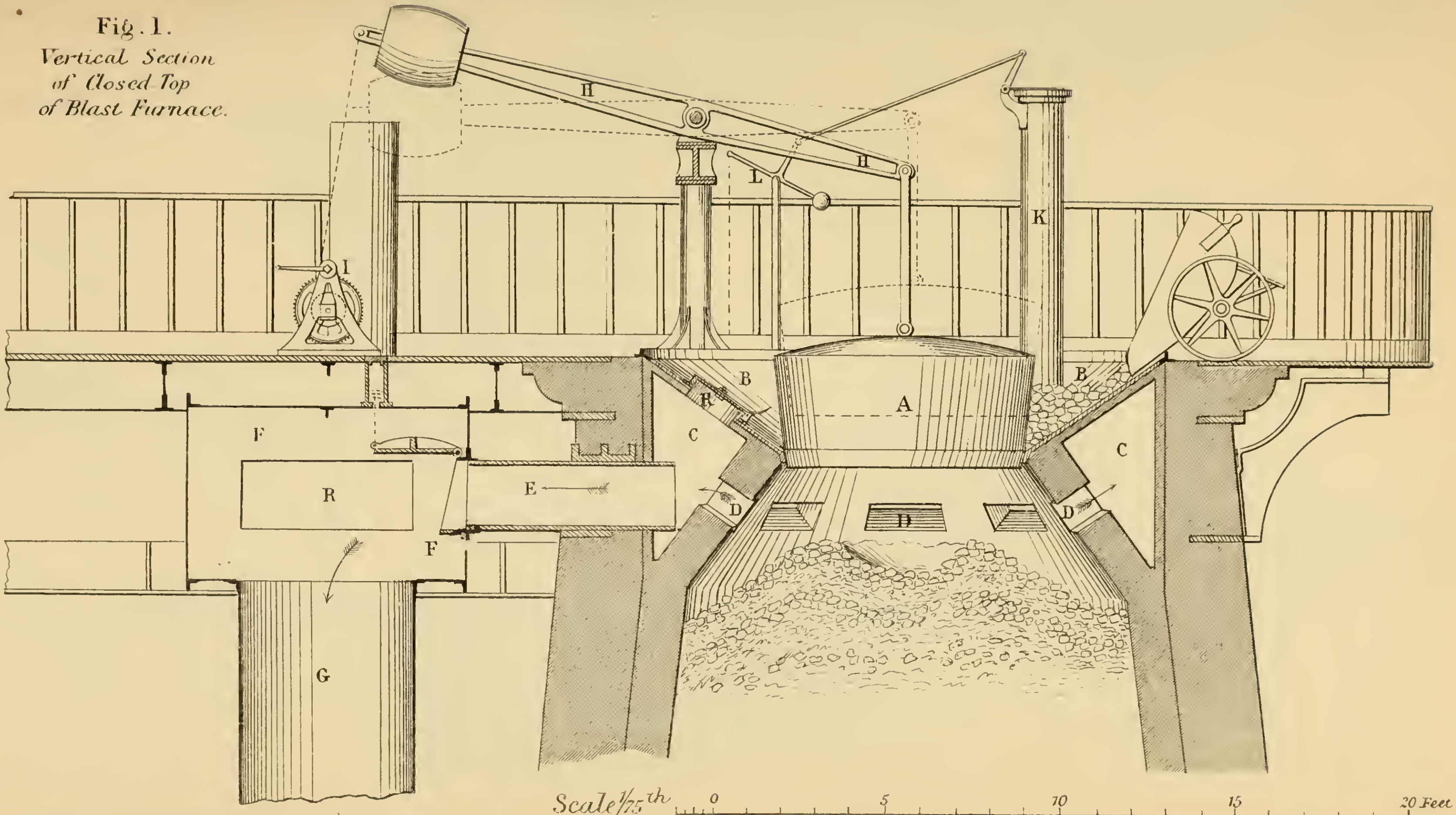
Fig. 15. *Tividale Colliery Rowley Eastern district.* (Table IV.)



(Proceedings Inst. M.E. 1860. Page 91.)

BLAST-FURNACE WASTE CASES.

Fig. 1.
Vertical Section of Closed Top of Blast Furnace.

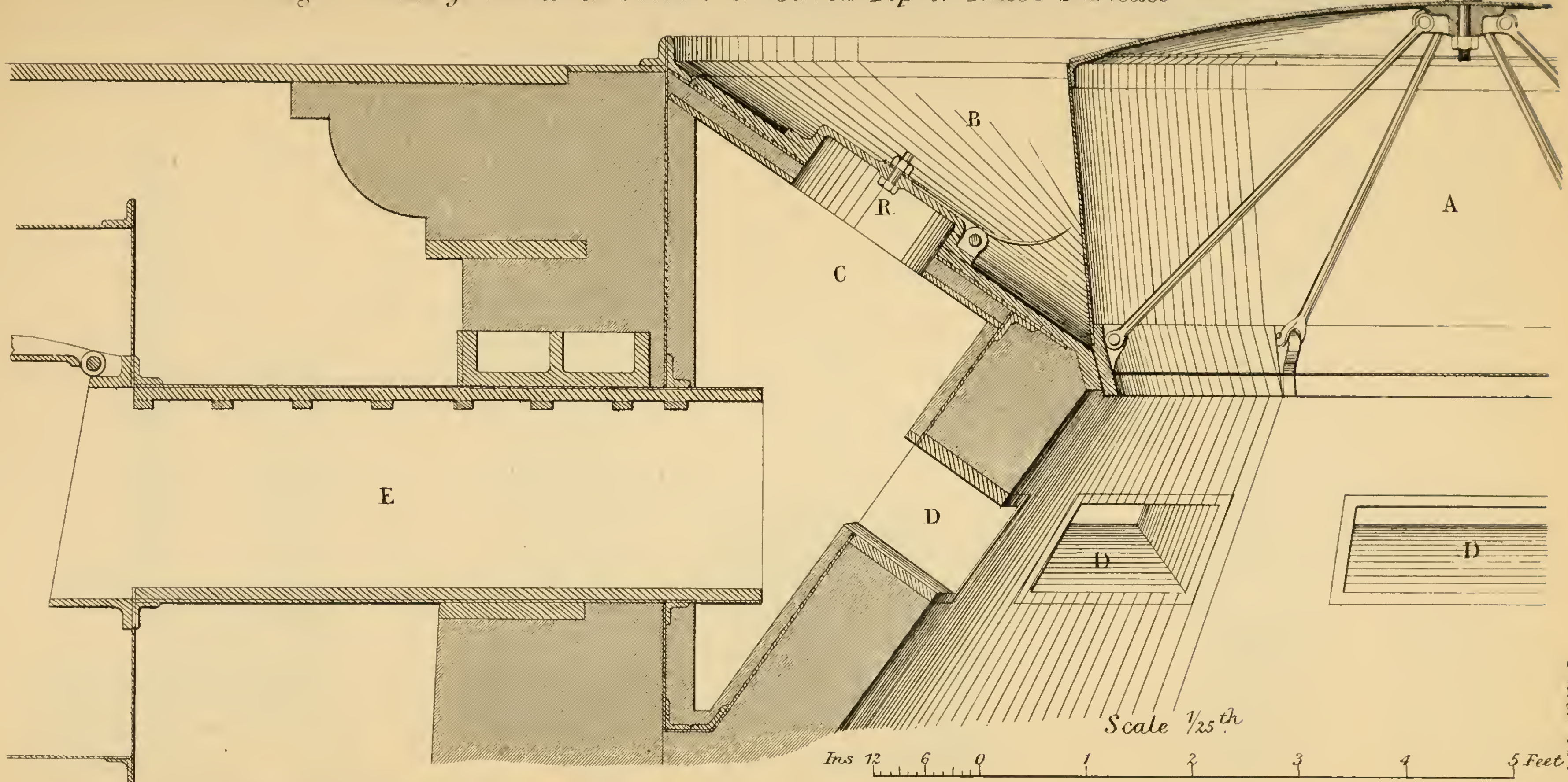


(*Proceedings Inst. M.E. 1860. Page 121*)

Plate 24.

BLAST-FURNACE WASTE GASES

Fig. 2. *Enlarged Vertical Section of Closed Top of Blast Furnace*



(Proceedings Inst. M.E. 1860. Page 121)

Plate 25.

BLAST FURNACE WASTE GASES.

Gas Pipes to Hot-Blast Stoves.

Fig. 3.

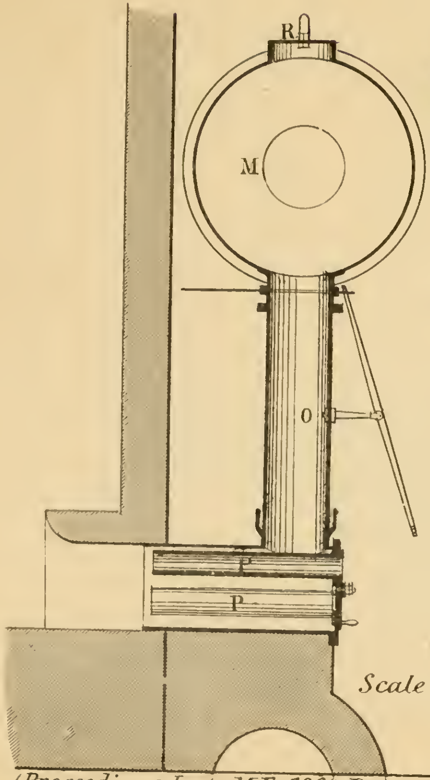
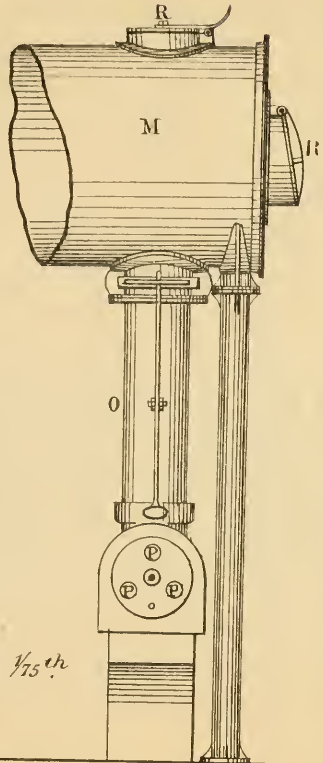


Fig. 4.



Scale 1/75th.

Fig. 5.

Mode of conveying Waste Gases from Blast Furnace to Hot-Blast Stoves

Scale 1/200th.

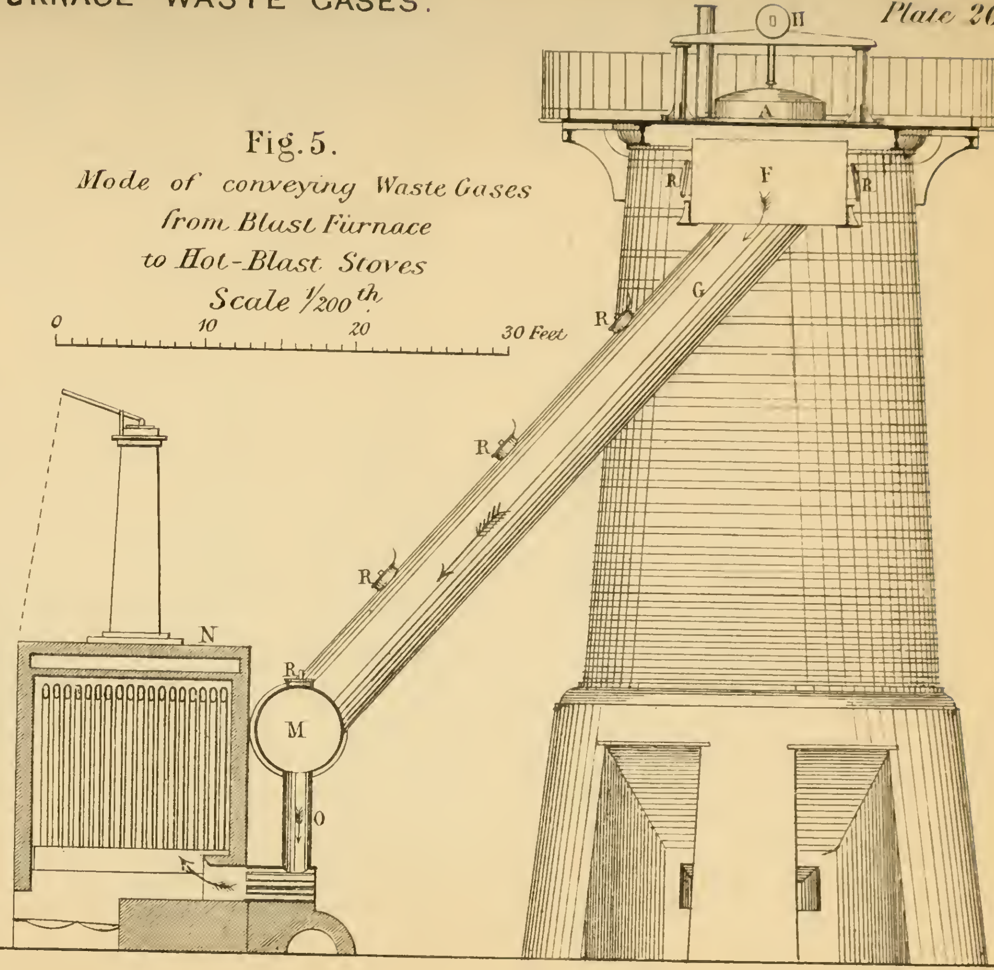


Plate 26.

PROCEEDINGS.

8 AND 9 AUGUST, 1860.

The ANNUAL PROVINCIAL MEETING of the Members was held in the Lecture Theatre of the Midland Institute, Birmingham, on Wednesday, 8th August, 1860; JAMES FENTON, Esq., Vice-President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The CHAIRMAN announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following New Members were duly elected :—

MEMBERS.

SAMUEL BAILEY,	Wednesbury.
PAUL BARKER,	Wednesbury.
FLEETWOOD JAMES CANNELL,	Wednesbury.
THOMAS CLUNES,	Worcester.
THOMAS ELWELL,	Paris.
BENJAMIN GIBBONS, JUN.,	Westbromwich.
GILBERT HAMILTON,	Soho.
JOHN HEAD,	Ipswich.
GEORGE HEATON,	Birmingham.
JAMES INNES HOPKINS,	Middlesborough.
WILLIAM HOWE,	Clay Cross.
HENRY LEA,	Westbromwich.
JOHN LEE,	Derby.
GEORGE PRIESTLEY MARTEN,	Bristol.
JAMES MCKENZIE,	Leeds.
WILLIAM OASTLER,	Worcester.

Edward Vincent Ponsonby, .	Worcester.
Allen Ransome, Jun., . .	London.
Thomas William Rumble, . .	London.
Henry William Schneider, .	Ulverstone.
Henry Smith, ...	Brierley Hill.
Richard Smith, . . .	Dudley.
James Evers Swindell, . .	Dudley.
Samuel William Worssam, .	London.

The Chairman congratulated the members on the success which had attended the annual provincial meetings of the Institution, of which this was now the fifth; and observed that the large accession of new members on the present occasion was highly gratifying.

The following paper was then read :—

ON THE TEN YARD COAL OF SOUTH STAFFORDSHIRE AND THE MODE OF WORKING.

BY MR. WILLIAM MATHEWS, OF CORBYN'S HALL IRON WORKS, DUDLEY.

In the present paper it is not proposed to enter into any elaborate or scientific discussion of the South Staffordshire coalfield, but simply to describe that most important portion of it known as the Thick, Main, or Ten Yard Coal: a seam peculiar to this district, nothing similar having been found in this country or indeed in any other part of Europe, and on the occurrence of which the importance of the district, as well as its high character for the manufacture of iron, is chiefly founded. For this object it will be convenient to consider the subject under the following divisions:—

I. Geological character and extent of the South Staffordshire Coalfield, and of the Thick Coal particularly.
II. Mineralogical peculiarities of the Thick Coal.
III. Modes of Working the Thick Coal, and methods of Ventilation.
IV. Area of Thick Coal remaining unworked, and its probable duration at the present rate of working.

I. *Geological character and extent of the South Staffordshire Coalfield, and of the Thick Coal particularly.*

The South Staffordshire Coalfield has been very closely investigated and described, not only by local men of intelligence and science, but more elaborately by Sir R. I. Murchison in his "Silurian System," and by Mr. Beete Jukes in his recent volume on the "South Staffordshire Coalfield" (1859), which exhausts all the knowledge at present attained on the subject. It will suffice therefore to confine this part of the paper to a reference to the accompanying general plan of the coalfield, Fig. 1, Plate 16, compiled from the geological ordnance survey, in which the extent of the coalfield is shown by the shaded portion. This plan comprises the whole

mineral basin of South Staffordshire and East Worcestershire, which it will be seen is flanked by the great red sandstone faults of Great Barr and Cannock Chase on the east, and of Stourbridge, Kingswinford, and Wolverhampton on the west; which by their junction on the north and south limit the coalfield in those directions. The extreme length north and south is about 26 miles, and the width at the widest part about 6 miles, giving an area of 90 to 100 square miles. The whole coalfield rests unconformably on the upper silurian limestone, which comes up to the surface at several points, rising at the Wren's Nest Hill and Sedgley Beacon to an elevation of 730 feet and upwards above the sea level.

Upon this plan is further delineated by the black portion the region of the Thick Coal, occupying the whole of the southern area of the field. In the northern portion of the seam, namely that east of the Dudley limestone ridge, the working operations have been actively carried on for a long series of years; and it is on the southern portion that the district has now to depend for its chief supply of Thick coal. In this portion of the district only are the limits of the Thick coal still undefined, no proofs having been made further south than those at Cradley, Corngreaves, and Hawn near Halesowen, where the seam exists in perfect regularity, dipping slightly southwards. To what extent therefore the Thick coal may extend in this direction, what may be its quality or character, or what the difficulty of winning it, are problems yet to be solved. The extension of railways however into that locality, for which acts have been recently obtained, coupled with the pressing wants of the neighbouring ironworks and the rapid exhaustion of the Thick coal in other portions of the seam, must effect this solution at no very distant day. The disfigurement of the landscape follows as a natural result: already some of the fairest portions of that neighbourhood are invaded by the inexorable march of mineral operations, and the classic scenes of Hagley may ere long give place to the unsightly appliances and ungenial aspects of the dark genii of the coal mines. The northern limit of the Thick coal may be roughly defined by a line drawn from Monmore Green eastwards, a little north of Bilston, to Darlaston; whence the boundary trends in a southerly direction to Westbromwich, where the coal is terminated by

the Great Barr sandstone fault before-mentioned, which forms its eastern boundary: the Kingswinford sandstone fault forming the natural boundary on the west.

The general lie or position of the Thick coal will be more clearly comprehended by a reference to the sections of the coalfield, Figs. 2, 3, and 4, Plates 17 and 18. The first, Fig. 2, Plate 17, is a section from south to north, extending from the the foot of the Clent Hills, through Dudley, Bentley, Norton, and Beaudesert, to Brereton near Rugeley, as shown by the dotted line from S to N on the plan, Fig. 1: the only portion to be referred to in connexion with the present subject is that terminating the Thick coal at Darlaston. The second section, Fig. 3, Plate 18, is taken from west to east, through Kingswinford, Dudley, and Westbromwich, as shown by the dotted line on the plan, commencing from the upper red sandstone measures, and crossing the coalfield through the limestone of the Dudley hills at right angles with the former section, and terminating with the permian or lower red sandstone at Westbromwich. The third section, Fig. 4, Plate 18, is also taken from west to east, parallel to the previous section, along the line W to E on the plan, passing through the basalt of Rowley.

Whilst however the Thick coal generally prevails over the area above indicated, it will be observed from the sections that it is by no means uniform and unbroken in its distribution. The boundary is somewhat modified by a termination of the bed by outcrop in some spots, short of the sandstone faults; and the general uniformity of the seam is materially dislocated and disturbed by the intrusion of the igneous rocks of the Rowley hills and at other spots, and incidentally of the subjacent measures, as well as by the occurrence of faults more or less extensive. The great anticlinal axis running nearly north and south from Wolverhampton east of Halesowen to the Lickey Hill cuts the Thick coal into two nearly equal divisions, one lying to the east of Dudley, the other to the west, forming two separate districts. These districts are subdivided by minor disturbances, forming other separate local basins, which are again intersected in various directions by faults and dislocations that have the effect of further subdividing the seam of coal into separate areas or patches of a comparatively limited extent, so

as to interpose difficulties of a serious character to its effective working; difficulties which will have to be discussed more in detail presently, and which are only compensated by the great value of the seam itself.

II. *Mineralogical peculiarities of the Thick Coal.*

It is not within the province of this paper to suggest any theory as to the geological origin of the Thick coal: this has been done with great ability and originality of view by Mr. Jukes, in his recent work. With us its existence is a "great fact"; and until we have to grapple with it practically, this is all that concerns us. It may however be mentioned that Mr. Jukes considers the bed of Thick coal to have its origin physically in the close approximation of a number of seams of varying thicknesses, brought into contact by some fortuitous process; and this view is supported by the fact of the bed being divided by distinct partings into the several divisions constituting its entire thickness. It is further strengthened by the well grounded supposition that the several portions of the Thick coal in the Bilston district can be identified with a separate series of thin coal seams in the Wyrley district, into which they have extended; and further by the fact that in other parts of the district the coal called the Flying Reed, consisting of the two top measures of the Thick coal, is gradually separated from the main bed by the intrusion of many yards of various rocks, as shown in Fig. 6, Plate 19, forming thenceforth an independent workable seam of thin coal. The several divisions of which the Thick coal is composed are too strongly defined to admit of much difference of opinion as to the soundness of this theory. Indeed these different divisions are clearly marked, the seam being regularly separated by partings of shale, clunch, or smut; and are of a generally uniform character over the whole of the district, varying more or less in thickness, and influencing more or less the total thickness of the seam of coal.

A certain local nomenclature by which these divisions of the Thick coal are distinguished has been adopted by the colliers, varying somewhat in each of the two districts, which is shown by the sections of the Thick coal given in Tables I to IV (appended) and in Figs. 12 to 15, Plate 23; the three first taken in the western district, and the

fourth in the eastern, giving the thickness of each division of coal and of the partings separating them. Rude and unmusical as the nomenclature in these tables sounds, it has at least the authority of antiquity to support it; for so far back as 1665 Dud Dudley, whose name is conspicuously eminent as an authority on the making of pig iron from pit coal, refers to similar terms of designation as then in use. He mentions that "the three uppermost measures are called the white measures, from the white arsenical salsuginous and sulphurous substance which is in them; and the next measures are the shoulder coal, the toe coal, the foot coal, the yard coal, the slipper coal, the sawyer coal, and the frizzy coal: the last three coals being the best for the making of iron, though other coals may be made use of."

The character of the coal in these several divisions and the greater or less thickness of the partings materially influence the cost of getting the Thick coal, as well as its marketable value, which is subject to great variations under the same or nearly the same conditions of the market. Hitherto this coal has been found of the highest excellence on the northern extremity of the basin; and it is there that the earliest workings commenced, partly by reason of its accessibility, but chiefly from the excellence of its quality at the outcrop. In that portion of the district lying between Wednesbury and Bilston on each side of the main north road, known as Wednesbury Old Field and King's Heath, the vestiges of old workings which are known to have been in operation as early as the year 1315 are spread over a large area. In 1577 deaths are recorded of men killed in the coal pits at Wednesbury. The method of working appears to have been by means of what are called "bell pits," in which after the pits were sunk the coal was excavated as far round the bottom of the shaft as could be done with safety; and when all the coal that could be thus worked was abstracted, other pits were sunk and subjected to the same process. As the coal was shallow and the sinking therefore inexpensive, the cost of getting by this mode was very moderate. Plot in his history of Staffordshire (1686) speaks thus of the coal in this locality:—"The smithies and kitchen fires are much better supplied by the common coal of the country, especially that of Wednesbury, Dudley, and Sedgley, which some prefer to the Cannel itself; the

texture and other qualities being such that it is a flat shining coal, having a pretty open grain, lying seldom level with the plane of the horizon but most times somewhat inclining to it, according to which it cleaves into blocks at the discretion of the workman; and it burns away with a sweet bright flame and into white ashes, leaving no such cinder as that from Newcastle-on-Tyne: the beds lying sometimes ten, eleven, or twelve yards thick; nay, I was told that at Ettingshall, in a place called Moorfields, the bed of coal is fourteen yards thick; insomuch that some acres of ground have been sold for £100 per acre. I was informed of one acre that sold for £150, and well indeed it might be so, for out of one single shaft there have been sometimes drawn £500 worth of coal. Nor could the country well subsist without such vast supplies, the wood being most of it spent upon the ironworks; for it is here, as well as in other countries that fetch their winter supply from hence, thought not only fit for the kitchen, but all other offices, even to the parlour and bedchamber; and not only in private families, but now too in most if not all the mechanic professions (except the ironworks) that require the greatest expense of fuel, as the glass houses, salt works, brick making, and malting, all of which were heretofore performed with wood or charcoal, especially the last, which one would think should hardly admit of the unpleasant fumes of such firing; nor indeed does it, no more than of wood, for they have a way of charring it in all particulars as they do wood, whence the coal is freed from those noxious steams that would otherwise give the malt an ill odour. The coal thus prepared they call cokes, which conceives as strong a heat almost as charcoal itself, and is as fit for most other uses, but for melting, fining and refining iron which it cannot be brought to do, although attempted by the most skilful and curious artists." The invention of the steam engine, and its application to the process of pumping the water from the mines, soon placed this rich district under more extensive requisition: and the excellent quality of the coal commanded for many years a high price in the market; for household purposes the celebrated Wednesbury Thick coal being noted far and wide. In addition to these ancient Wednesbury workings, the coals of which do not at this period appear to have been applied in any way to the manufacture of iron, operations in the Thick coal were carried on

to some extent on Pensnett Chase, in the western portion of the district; and it was in this locality that Dud Dudley tried his first experiments in iron making. He says, writing in 1665 :—"There are at least within ten miles of the castle of Dudley twelve or fourteen coal works, some in Worcestershire and some in Staffordshire, now in work, and twice as many not in work; each of which gets two thousand tons of coal yearly, and some three, four, or five thousand tons of coal yearly: and the uppermost or top measures of coal are ten, eleven, and some twelve yards thick; the coal ascending, basseting, or cropping up to the surface of the earth, and there the colliers formerly got it; but where the coal is deep and but little earth upon it, there the colliers rid off the earth and dig the coal under their feet; these works are called 'foot rids.'"

There is a marked distinction in the mineralogical character of the Thick coal in the two portions of the district. In the Wednesbury district the coal in the greater portion of the beds is generally of a more compact and crystalline character, breaking up into large cubical fragments, burning with a strong heat and leaving a comparatively small residuum of ash. It is therefore better adapted for domestic use or gas making, and commands in consequence a higher selling price. An exception must be made however in respect of the coal in the Oldbury district, where, owing probably to the proximity of the basalt of the Rowley Ridge on the west and the red sandstone fault of Westbromwich on the east, the quality is much deteriorated, the coal possessing neither the requisites of a good house coal nor suitability for iron smelting, and reaching therefore scarcely half the value per acre of the same seam in the Wednesbury district. In the region west of Dudley, although the qualities ascribed to the Wednesbury coal attach in some degree to a portion of the Thick coal, yet generally speaking it has a more dark and earthy texture, breaking with a tough and fibrous rather than with a short and granular fracture, and exhibiting clearer indications of vegetable origin. It is therefore better adapted for iron smelting, and has been held in higher estimation for that purpose from the days of Dud Dudley downwards: the pig iron made there being generally better in quality from the same ores where this coal is used.

III. *Modes of Working the Thick Coal, and methods of Ventilation.*

Enough has perhaps been stated now to give a fair idea of the situation and geological conditions of the Thick coal; and guarded as it is by the spirits of earth, air, and water, it remains to be considered how to attack and win this golden fleece.

For this purpose any given area may be taken, say 20 acres, included within any of the known faults which have been ascertained and laid down with so much accuracy by Mr. Jukes. The first step will naturally be to ascertain the inclination or dip of the coal, and the probable extent of water to be encountered; and then to mark out the proper site for two or three shafts. This done, it is necessary to erect a steam engine of the requisite power not only to wind up the coal from any probable depth when won, but also to pump whatever quantity of water the mine may yield. Two shafts are usually sunk of 7 or 8 feet diameter and about 24 feet apart, which are ventilated by drifts from one to the other as the sinking proceeds. In case of much water being found, a third shaft is sunk, into which the water from the other two is conducted and pumped up to the surface; or else the water is coffered out with brickwork, which serves the same purpose as iron tubbing, whereby the water is stopped back to prevent it flowing into the shafts at all. It is usual to sink one of the shafts a little lower than the coal, as shown in Figs. 5 and 6, Plate 19, to provide what is called "sump room" or space to hold any small accumulations of water the mine may yield; from which, when there is no need for a pumping apparatus, the water is drawn by barrels as often as requisite. For ventilation one of the shafts is appropriated as a downcast, through which the fresh air enters the mine; and the other is the upcast shaft, up which the vitiated air that has passed through the workings is conducted; and a communication closed by doors is made between the two shafts. When all is completed relating to the shafts, and a stable for the horses excavated in the coal near the bottom, the next process is driving out the gate roads along which the coal is conveyed, and the air heads through which the foul air is brought back from the workings to the upcast shaft.

The gate roads, Figs. 5 and 7, Plates 19 and 20, are cut 9 feet high and 9 feet wide; and this is effected by the pikeman undergoing or cutting the coal horizontally at the bottom, excavating $4\frac{1}{2}$ feet inwards 8 feet in width, making 36 square feet by 18 inches thick, for a "stint" or day's work. This bottom cutting or undergoing is carried inwards some 15 or 18 feet, of the width of the gate road, 9 feet. One side is then cut up 18 inches thick to the top of the Slipper coal (see the sections of the Thick coal in Figs. 12 to 15, Plate 23, and Tables I to IV appended), in stints of 3 feet vertically and 12 feet inwards, making 36 square feet per day; and this done, the coal is broken down from the fast side by mechanical means, wedge or gunpowder, and removed by the various workmen. The air head is driven at the same time, generally in the Tow coal, the fourth seam from the top; and a communication is made from it to the upcast shaft. The dimensions of the air head are about 4 feet high by 4 feet wide, giving a sectional area of about 16 square feet. It is usual to drive two gate roads, one from each shaft, in the same or in opposite directions, the air heads from each being conducted to the upcast shaft. When the two gate roads are driven in the same direction and the mine is tolerably free from gas, the ventilation is effected by the gate roads alone, and the use of the air heads is dispensed with. Communications or "spouts" are made at certain intervals between the air head and the gate road, so that a proper supply of fresh air may always be secured close up to the spot at which the workmen are employed, an attention to which is of great importance.

When the gate roads are completed, the next process is to open off the work, and in this operation arrangements are made for getting out as large an area of coal in each panel or "side of work" as is practicable. This is more or less controlled by the nature of the coal, and the quantity of rubbish, technically called "gob," to be left behind in the pits as worthless, which from its tendency to heat by the decomposition of the iron pyrites contained in it renders the risk of fire more or less imminent. In opening off, the first step in the ordinary "Rib and Pillar" system of working, shown in section and plan in Figs. 5 and 7, Plates 19 and 20, is to drive two lateral openings about 9 feet wide, called "bolt holes," about 100 feet apart,

of a length equal to the proposed thickness of the rib intended to be left as a support on each side of the gate road, usually about 30 feet. The process of undergoing the coal is then commenced, for which lengths of about 30 feet are marked off for working space, leaving alternate intervals of 24 to 30 feet as pillars for the support of the roof; and this marking off is repeated according to the number of pillars it is proposed the "side of work" should contain. The mode of undergoing is the same as that described in driving the gate roads; four or five men working in a row and in a horizontal position, each excavating 6 feet by 6 feet or 36 square feet horizontally and 18 inches thickness for a "stint" or day's work. The successive stints are shown in the plan, Fig. 7, Plate 20, by the dotted lines at AA. A square of 6 feet in the middle of each space of 30 feet thus undergone is then underbuilt, partly with timber packings; on which is left a minor pillar, or "man of war" or "cog," which is eventually taken away, but which serves temporarily to support the coal in the opening over the men. The cogs are underbuilt with timber in order to admit of a slight settling taking place, which renders them less liable to split or be thrown out of place by the superincumbent weight. When the undergoing has been carried in 15 or 18 feet, the second process of cutting through the Slipper coal vertically on one side is effected, 12 feet inwards by 3 feet height and 18 inches thickness being cut for a day's work. The coal being set at liberty on the side so cut is broken off on the other by wedging or blasting, and then removed by subordinate workmen attendant on another class of men called the "bondsmen," whose business it is to load the coal on to the skips or carriages by which it is conveyed on railways to the pit's bottom. The next process is to cut the third section of coal, the Sawyer and Patchels coals, which is effected in a similar manner, as shown at B, Fig. 5, Plate 19, and in the sections of Thick coal, Tables I to IV.; and so on to the fourth cutting in the Stone coal C, Fig. 5. This completes the cutting of the bottom coals which are then broken down and removed. The upper portions of the bottom coals are reached by raising the floor with the slack and refuse produced in cutting the lowest measures. The cuttings are made round the pillars and cogs, as shown in the section, Fig. 5, Plate 19.

The fifth cutting D, Fig. 5, Plate 19, begins the top series of coals, and is in the Veins and Fine coals, which are reached by means of a scaffold. Here commences the most hazardous part of the process: the underbuilding of the cogs is then removed, and the cogs themselves come down throughout the entire height of the coals recently cut: the remainder of the coals uncut, being thus deprived of their support in the centre, deflect, or in the language of the collier "swag," and occasionally fall down more or less suddenly without further interference. Their tendency to fall is tested by the overman from time to time by tapping them in various places with the pike. When the cogs are removed the floor of the mine usually "creeps" or is forced upwards by the pressure of the permanent pillars, as shown in the section, Fig. 5; which affords greater facilities for reaching the upper coals in the further process of cutting in. If the upper coals have not already fallen, the sixth cutting is made in the Brazils coal, the seventh in the Tow coal E, Fig. 5, and the eighth in the White coal, as at F. During the cutting, the top coal is partially supported by wooden spirns or wedges driven upwards into the cuttings, which are withdrawn as soon as the preparations for falling the coals are completed. The remaining measures, namely the Spires and Roof coals, are seldom cut, or if cut at all only half through, and are eventually forced down by the workman acting upon them with a long pole armed with a strong pricker. In cases where the measures immediately above the coal are weak and friable, the top measure of coal is left for a roof. At this stage of the proceedings it is necessary to remove the gob or rubbish, which by this time is beginning to heat; the larger fragments are piled round the permanent pillars, as shown in Fig. 5, which they serve to support in some degree, and the small is distributed by boys about the floor of the mine. When all the coals, excepting the pillars permanently left, are thus removed from each panel or side of work, and as large an area worked as is consistent with safety, which may vary from four to ten pillars according to the character of the coal, dams or air-tight stoppings are built in the bolt holes, to prevent fire by cutting off all communication with the external air.

It is in cutting in the top series of coals that the danger to the collier chiefly arises; and it is only to men of experience, vigilance,

and activity, that this department should be entrusted, the coal often coming down before the cutting is completed: usually however giving some previous warning by a peculiar crackling sound, which the men instantly recognise and hastily quit the scaffold and retreat to some place of safety. In addition to this special source of danger, great risk is further occasioned by the extensive occurrence in the Thick coal of numerous dislocations called "slips" and "things," with which the whole seam is reticulated, and which form natural partings that the workmen have no previous knowledge of. When these are intersected in cutting the coals, it frequently happens that the coals fall without any warning, and the unfortunate workman is crushed beneath them. The records of the loss of life from this cause place South Staffordshire in a melancholy pre-eminence in comparison with other districts, as will be seen by Table V (appended), compiled by Mr. Greenwell, of Radstock, Bath, from the reports of Government Inspectors of Mines and from Mr. Hunt's Mineral Statistics.

During the process of working, the ventilation is effected by carrying on the air heads into the side of work as high in the coal as may be found needful to clear the upper part of the work of any gas that may be given out: the fresh air traversing the gate road and through the bolt hole and circulating freely round the part of the work where the men are employed, making its exit by the air head into the upcast shaft, as shown by the arrows in the plan, Fig. 7, Plate 20. Some practical difficulty arises from the occasional tendency of the current of air to stagnate or to reverse itself, to which it is more subject in hot weather, when the temperature of the mine and that of the external air become more equalised. The pits are then said to fight, and this can be remedied only by increasing the temperature of the upcast shaft artificially by a furnace connected with it, to stimulate the draught. At ordinary temperatures of the atmosphere however the higher degree of heat in the working places of the mine, usually from 65° to 70°, is itself sufficient to keep the current of air in motion at the rate of about 30 feet per second in the gate roads, and in the air heads at about 120 feet per second; which affords an abundant supply of fresh air for the efficient ventilation of as many sides of work as can be kept open at a time.

Now two cardinal points demand attention and enquiry in reference to this rib and pillar mode of working the Thick coal:—first, the apparently imperfect mode of ventilation; and secondly, the inadequate produce of coal per acre, considering the thickness of the seam.

As to the first, imperfect in some respects as the method of ventilation certainly is, it has not hitherto been found practicable to adopt any plan more effective; and on the whole very little complaint has to be made under this mode of working the Thick coal, with the ordinary vigilance which it is incumbent on every manager of a mine to exercise. Other plans have been devised and partially acted upon, but they have not become satisfactorily established. One only of these may be briefly described, chiefly on account of its having been originally promulgated by Mr. B. Gibbons of Shut End, whose name as connected with both the iron and coal trades bears an authority of the highest character, no two men having initiated improvements of a more beneficial nature to those trades than this gentleman and his brother, the late Mr. John Gibbons. In this plan of ventilation, instead of fresh air being supplied to the workings by means of the upcast and downcast shafts in the ordinary mode, each shaft is made to ventilate its own workings by the addition to the shaft of what is called a "trumpeting" or smaller supplementary shaft, as shown in Fig. 11, Plate 22; in connexion with which a ventilating furnace and chimney are erected at the surface for the purpose of artificially increasing the natural draught of the pit. It will be seen that this trumpeting is a substitute for the ordinary upcast shaft; and the chief objections to it are, first, its original expense, which, if it is made sufficiently capacious to be effective, is nearly equal to that of a separate upcast shaft; and secondly, its limited dimensions and consequent liability to derangement. These objections have deterred the practical managers of mines in South Staffordshire from adopting the plan.

In the present state of the Thick coal seam, the risk of accident from fire damp is far less than that when mining operations first commenced in it. The carburetted hydrogen gas, in which it is so prolific, escapes wherever any incision is made in the coal by which a vertical section of its laminæ is exposed to the air. This may be readily

tested by the application of a candle to the portion of coal cut through in sinking the shaft, when flashes of ignited carburetted hydrogen gas, which escapes with a singing noise, occur wherever it comes in contact with the flame. The great extent to which the Thick coal is now cut up in all directions affords such abundant channels of escape for this gas, that the enemy, which was formerly so dangerous to encounter and difficult to subdue, is now by the aid of the safety lamp controlled with comparative ease. Before however the ventilation by the present system of high air heads and the use of the safety lamp were established, devises for dissipating the gas were adopted which would now be considered unjustifiably dangerous. Plot in his history of Staffordshire (1686), speaking of the mode of working the mines near Wednesbury, describes the mode of ventilation thus :—" In working the mine much inconvenience is experienced by the presence of damp. One sort is expelled either by water, or by letting down an iron cradle, as they call their lamp, filled with fire, into the shaft or the bye pit next to that they intend to work; which making a draught draws away the foul air. Another sort is expelled by a person entering the pit before the workmen, covered with wet sackcloth; when he comes near where the damp is feared, he creeps on his belly with a long pole before him having a lighted candle upon the top of it; which coming in contact with the foul air, it explodes and escapes by the mouth of the pit, the person that fired it escaping by creeping on the ground, keeping his face close to it till it is over." Even down to modern times, schemes as daring and hazardous as that described were the common resource in many parts of South Staffordshire. In the Netherton district, south west of Dudley, the coal in the early part of the present century was rendered almost unworkable from the abundance of this gas, which set at defiance any of the them known modes of working. The ventilation was effected by a current of air travelling the gate roads alone by the down and upcast shafts, the roads themselves being ventilated during the process of driving by side air heads or troughs; but the escape of gas was so abundant that even in the roads the air could scarcely be kept below the inflammable point. In all those portions of the mine therefore above the level of the gate roads the gas naturally accumulated in excessive quantities,

and it was a troublesome as well as a dangerous process to clear the mine in the morning of the accumulation of the previous night. This was usually done by exploding the gas by means of the firing line, which was a contrivance for raising a lighted candle into the higher parts of the mine by means of a pulley and string fastened to the top of a pole, by which the candle was gradually drawn up by the fireman, who with his assistants was ensconced in some place of safety adjoining and thus exploded the gas. It is needless to enlarge on the danger, inconvenience, and lamentable loss of life and waste of property which was involved in this process. Nevertheless it was the only mode by which the working of these fiery mines could be conducted in the existing state of mining knowledge at that period. It was not until about the year 1810 that any material improvement was effected, when a mining engineer named John Ryan, an Irishman, made his appearance in that district and proffered his services to free the fiery mines in the neighbourhood of Netherton from fire damp, at least to such an extent as to make them comparatively safe to work. Whether he redeemed this pledge to the full extent of his professions is doubtful; but it is certain that he effected very considerable improvement in the ventilation. His plan was to surround the workings with a separate air head carried up high in the coal, into which all the foul air and inflammable gas were conducted and carried to the upcast shaft: and although it was found that the requisite conditions in the coal for carrying out this plan in its integrity could not be met with in practice, yet modifications of it were adopted, and the present mode of ventilation is unquestionably the offspring of his genius. The courage and perseverance with which Mr. Ryan prosecuted his system were deserving of the highest praise, and the danger which he personally encountered and the resolution which he displayed were such that he was familiarly known among the colliers by the name of "hell-fire Jack," He may be remembered by many coal owners of the present generation by the importunity with which he continually urged upon them the righteousness of coroner's juries finding a verdict of wilful murder in all cases of deaths from explosions in those collieries in which his system of ventilation was not acted upon. The introduction about the year 1815 of the safety lamp of Sir H. Davy into

mines of a fiery character was an invaluable aid both as regards the safety of life and the practical facility of working. By its use not only was the presence of the enemy detected, but it admitted of means being adopted by the workman for dissipating the gas under circumstances that were quite impracticable with a naked light; and it may be safely said that no greater boon has been conferred on mankind than that which has been given by this admirable invention to the miner.

Whilst however it is the business of the manager of a Thick coal mine to adopt measures for ample ventilation, some precautions are necessary against a too abundant supply of fresh air, by which the natural tendency of the gob to fire is greatly increased; and in avoiding Scylla therefore care must be taken not to run foul of Charybdis. This is one of the difficulties of the miner's craft, and one with which the earliest miners had to contend. "These small coals," writes Dud Dudley in 1665, "produce often great prejudice to the owners of the works and to the work itself, and also to the colliers, who cast the small coals together; which compelling necessity forces the colliers to do for two causes: one is to raise them to cut down the ten yards thickness of coals, of which they draw only the bigger sort of coal, not regarding the lesser or small coal which will bring no money, saying 'he that liveth longest let him fetch fire further:' next, the colliers must cast these small coals and slack or dross out of their way, which sulphurous small coal and crowded moist slack heat naturally and kindle in the middle of those great heaps, often setting the coal works on fire and flaming out of the pits and continuing burning like Ætna or Hecla." It is the duty of a prudent miner to leave as little refuse forming the gob as possible in each side of work; and if it fire, to have the work sufficiently at command to be able immediately to exclude the fresh air by the erection of dams in the bolt holes or entrances to the side of work, and thus extinguish the fire by depriving it of air.

The second point demanding attention,—the insufficient produce of Thick coal per acre,—has long been a source of perplexity to the enquirer. A seam of Thick coal 10 yards thick contains 48400 cubic yards per acre, each cubic yard weighing 1 ton of 2240 lbs., making 48400 tons per acre; and deducting one fifth for partings and spoil,

38720 tons of clear coal are left as the produce of one acre. But the first working by the rib and pillar system already described does not usually produce more than about 15000 to 16000 tons per acre; rarely more, frequently less. This produce however represents the usual nominal selling tons by boats and otherwise, prescribed by leases and the custom of the trade, of which it is difficult to define the exact weight; also the coal allowed to colliers and the small coal consumed at the steam engine, of which no account is taken, have to be added: and these together will bring up the actual produce to probably little short of 19000 or 20000 statute tons per acre. To this has to be added the produce of the after working of the ribs and pillars, which is a much more expensive and yet distant process; which will bring the total produce probably to 23000 statute tons per acre, a quantity however much less than that produced by the other mode of working called the "Long Wall" system.

In the "Long Wall" system of working, the Thick coal seam is divided into two workings, of such a thickness each as will admit of the whole of the coal in each division being cleared out, instead of leaving ribs and pillars as by the rib and pillar system previously described; the top portion being worked first. The mode of working is shown in section and plan in Figs. 6 and 8, Plates 19 and 21. The driving out of the gate roads is effected as in the rib and pillar system, and one or more main gate roads are carried forward from the shaft to the outside of the portion of coal proposed to be worked, usually in the Brazils measure about 16 feet from the top of the seam (see the section in Fig. 14, Plate 23, and Table III appended). On arriving at the outside boundary, lateral openings are made right and left of the road, and driven along sufficiently far until space is gained for the commencement of a regular face of work. The holing or undergoing is then begun, and the coal cut and broken down progressively, the colliers working back towards the shaft, and "leaving," as they describe it, "all their troubles behind them." At the outset of the operation it is necessary to cut the coal vertically in the manner previously described in the rib and pillar system; but the "shut," or the part of the roof left behind, soon begins to break down, and the coal over the holing comes down of its own accord; by leaving

cogs behind them the workmen protect themselves against any premature fall of the roof, until it can be allowed to come down without danger. "In this manner," says Mr. Brough, "they keep sweeping fine sides of work homewards, just as the mowers sweep away swathes of grass in a hayfield. The rock or shut follows them, and with it they build the most useful fortifications in the world. Thus with a face of coal in front, so spragged (underbuilt) that all danger is out of the question, and a building behind them as strong as a castle, it would be surprising indeed if the workmen got the slightest hurt, much more lost their lives." When the whole upper portion of the coal has been thus abstracted, the bottom portion is worked in the same manner; a few feet of coal being left in the middle of the seam to serve as a roof for the lower working. The ventilation of the working is shown by the arrows in the plan, Fig. 8, Plate 21.

It must be admitted that in point of safety to the men, as well as in the larger produce of coal per acre, the long wall has a manifest advantage over the rib and pillar system. The ventilation is perfect, the current being kept in a continual stream along the working face, with very little liability to disturbance: and the produce of coal on a moderate estimate is from 5000 to 7000 tons per acre more than in the rib and pillar system. On the comparative advantages of these two modes of working the Thick coal a great deal has been said and written both by coal owners, professional viewers, and mine inspectors; but many of the special circumstances that determine either mode in any particular instance have either been ignored or overlooked. It is beyond question that by the rib and pillar system a certain loss of coal is involved compared with the long wall system: but it must be borne in mind that the value of the Thick coal depends mainly on the size in which it can be sent into the market, the selling price gradually decreasing with the bulk, so as to afford a range of from (say) 10*s.* to 2*s.* per ton in coal of the same quality; a distinction quite unknown in the bituminous coal of the North of England. Now if a much greater proportion of large coal at the higher selling prices and less of the small coal or slack at the lower selling prices can be obtained by the rib and pillar system, it may happen, and in fact does frequently

happen, that the pecuniary value of the smaller product per acre may exceed that of the larger: and inasmuch as the royalty is usually based on the selling price per ton, it is the proprietor's interest to have that mode of mining adopted which will yield him the largest return per acre. Hence in most of the leases under which the Thick coal is worked there is an express stipulation that the system of mining shall be restricted to the ordinary rib and pillar mode of working. It is true that, owing to the increased demand of the iron-works for the rough slack used at the puddling and blast furnaces, the price of this description of coal has approximated of late much more closely to that of the large coal than was formerly the case; and greater latitude is consequently allowed for the adoption of any improved mode of working. But it must be borne in mind that many conditions are requisite to admit of the long wall system being adopted: such as ample extent of mining ground, absence of faults, facility for consumption of the coal in all shapes, and freedom from legal restrictions; a combination of advantages rarely attainable. It is but justice therefore to the character of South Staffordshire to say that, in some of the larger undertakings in the western portion of the district where these conditions are met with, improved modes of working have been long in use. A reference however to the sections of the coalfield in Figs. 2, 3, and 4, Plates 17 and 18, will show the dislocated and irregular character of the Thick coal throughout the district, of which an instance is shown in Fig. 9, Plate 22, exhibiting the position of the Thick coal in one of the Corbyn's Hall Collieries; a disturbed condition of the seam by no means infrequent. In such cases the adoption of the long wall system or indeed of any regular system is quite impracticable, the mode of working being influenced by the actual condition and form of the seam.

IV. *Area of Thick Coal remaining unworked, and its probable duration at the present rate of working.*

As regards this final branch of the subject, there is of course considerable difficulty in obtaining sufficient data to admit of accurate calculation; and any estimate framed on such data as are within reach must therefore be to a certain extent vague. All that can be done is

to ascertain from the most authentic sources the area unworked in each portion of the district, the weekly or annual quantity of coal got, and the number of tons each acre is considered to yield : this will give the total number of tons remaining in each portion, and hence the period of duration.

In the eastern portion of the district the extent of Thick coal remaining unworked may be estimated at about 1160 acres, yielding in the first and second workings about 20,000 tons per acre, making a total of 23,200,000 tons. The present rate of working is about 11,000 tons per week, which for 50 working weeks amounts to 550,000 tons per annum. The probable period of duration is therefore about 42 years.

There is more difficulty in framing an estimate for the western portion of the district, owing firstly to the larger area unworked, and secondly to the absence of proof of the actual extent of the Thick coal in a southerly direction. The estimate is therefore confined to the limits previously mentioned as proved in that direction, namely from Stourbridge to Halesowen. With this limitation the area unworked is estimated at about 2785 acres, which at 20,000 tons per acre gives 55,700,000 tons. The present rate of working is about 30,000 tons per week, or 1,500,000 tons per annum. The probable period of duration is therefore about 37 years.

It will be obvious that the respective periods of duration here given will be materially modified by the greater or less rapidity with which the present workings are carried on, and still more by the extent of the area under which the coal may eventually be found to extend in the unproved portion of the district southwards. It is certainly reasonable to infer on every geological presumption that a large extent of Thick coal may yet be available for future working which is altogether excluded from this estimate. It may however be assumed that at the expiration of another half century this noble seam of coal, the pride and glory of South Staffordshire, will exist only in name : and the future importance of this busy hive of industry must be sought in other resources than that which has hitherto contributed so largely to its strength and prosperity.

TABLE I.

Section of Thick Coal
at Corbyn's Hall Colliery, Kingswinford.
Western District.
Rib and Pillar system of Working.
Fig. 12, *Plate* 23.

	Partings. Feet.	Partings. Ins.	Coal. Feet.	Coal. Ins.	
					TOP COALS.
Roof coal			1	9	Brought down by pricker.
Spires coal			1	3	
Parting	1	0			
White coal			3	0	8th cutting.
Parting	1	0			
Tow (or Toe) coal			3	9	7th cutting.
Parting		4			
Brazils coal			2	0	6th cutting.
Parting		6			
Fine coal			2	3	5th cutting: begins cutting of top coals.
Parting		3			
Veins coal			1	6	
Parting, Hard or Stone coal		10			BOTTOM COALS.
Stone coal			3	6	4th cutting: completes cutting of bottom coals.
Parting		4			
Patchels coal			2	6	3rd cutting.
Parting		2			
Sawyer coal			1	6	
Parting		3			
Slipper coal			3	0	2nd cutting.
Parting		2			
Benches coal or Kid coal			2	0	Holing or 1st cutting.
Total thickness of Coal			28	0	
Total thickness of Partings	4	10			
Total thickness of Seam					32 ft. 10 ins.

TABLE II.

Section of Thick Coal

at Ketley Colliery, Kingswinford.

Western district.

Rib and Pillar system of Working.

Fig. 13, *Plate* 23.

	Partings. Feet.	Partings. Ins.	Coal. Feet.	Coal. Ins.	
Flying Reed coal 5 feet thick					
Parting 11 feet thickening to 90 feet					TOP COALS.
White coal			3	0	8th cutting.
Parting	2	0			
Tow (or Toe) coal			3	9	7th cutting.
Parting		4			
Brazils coal			1	9	6th cutting.
Parting		6			
Fine coal			2	0	5th cutting: begins cutting of top coals.
Parting		3			
Veins coal			1	6	
					BOTTOM COALS.
Parting	1	0			
Stone coal			3	0	4th cutting: completes cutting of bottom coals.
Parting		4			
Patchels coal			2	6	3rd cutting.
Parting		2			
Sawyer coal			1	6	
Parting		3			
Slipper coal			3	0	2nd cutting.
Parting		2			
Benches coal			1	6	Holing or 1st cutting.
Thickness of Coal			23	6	
Thickness of Partings	5	0			
Thickness of Seam					28 ft. 6 ins.

TABLE III.

Section of Thick Coal

at Hawn Colliery, Halesowen

Western district.

Long Wall system of Working.

Fig. 14, *Plate* 23.

	Partings. Feet.	Partings. Ins.	Coal. Feet.	Coal. Ins.	
Roof coal			2	0	TOP COALS.
Spires coal			2	0	
Parting		6			
White coal			3	6	
Parting	3	0			
Tow (or Toe) coal			2	6	
Parting		6			
Brazils coal			2	0	Holing for first or top working.
Parting	1	0			
Fine coal			2	0	This portion not workable, being soft and shaly.
Veins and Slums coal*	1	0			
Parting	2	6			
Stone coal			3	0	
Parting		10			BOTTOM COALS.
Patchels coal			2	0	
Parting		10			
Sawyer coal			1	6	
Parting		2			
Slipper coal			3	0	
Parting	1	0			
Benches coal			1	0	Holing for second or bottom working.
Total thickness of Coal			24	6	
Total thickness of Partings	11	4			
Total thickness of Seam					35 ft. 10 ins.

* This coal is so shaly and soft as to be worthless, so that it is no better than parting. The Veins at Corbyn's Hall are good coal, and at Ketley also.

TABLE IV.

Section of Thick Coal

at Tividale Colliery, Rowley.

Eastern district.

Rib and Pillar system of Working.

Fig. 15, *Plate* 23.

	Partings. Feet.	Partings. Ins.	Coal. Feet.	Coal. Ins.	
Roof coal			4	0	TOP COALS. Brought down by pricker.
Parting		4			
Spires coal			2	2	
Jays coal			2	0	7th cutting.
Parting		1			
Lambs coal			1	0	6th cutting.
Tow (or Toe) coal			1	6	
Bench coal			1	6	5th cutting: begins cutting of top coals.
Brazils coal			1	6	
Parting		4			BOTTOM COALS.
Foot coal			1	8	4th cutting: completes cutting of bottom coals.
Parting		1			
John coal, or Slips or Veins coal			3	0	
Hard stone parting . . .		10			
Stone coal or Long coal . . .			4	0	3rd cutting.
Sawyer coal or Springs coals . .			1	6	
Slipper coal			2	6	2nd cutting.
Parting		1			
Humphrey's coal			2	3	Holing or 1st cutting.
Total thickness of Coal			28	7	
Total thickness of Partings	1	9			
Total thickness of Seam					30 ft. 4 ins.

TABLE V.

Deaths by Accident in Collieries in the years 1854 *to* 1858.

	Miscellaneous.		In Shafts.		By Falls of Coal.		By Explosions, &c.		Total.	
	Number of Deaths.	Tons of Coal raised per death.	Number of Deaths.	Tons of Coal raised per death.	Number of Deaths.	Tons of Coal raised per death.	Number of Deaths.	Tons of Coal raised per death.	Number of Deaths.	Tons of Coal raised per death.
Northumberland, Durham, and Cumberland . . .	269	306,386	122	676,209	263	313,679	68	1,213,199	722	114,262
Lancashire, Cheshire, and North Wales	162	325,443	254	207,566	291	181,171	405	130,177	1112	47,408
York, Derby, Nottingham, Leicester, and Warwick	66	955,273	161	391,602	208	303,115	288	218,917	723	87,203
Stafford, Worcester, and Shropshire	86	476,867	270	151.891	572	71.697	160	256.316	1088	37,693
Somersetshire, Gloucester, Monmouth, & South Wales	147	322.464	162	292,606	404	117.332	294	161.232	1007	47.072
Scotland.	41	961,237	130	303.159	181	209.631	54	729.828	413	95,125
Total	771	422,945	1099	296.716	1926	169,309	1269	256,968	5065	64.381

Mr. Mathews remarked that the estimate given in the paper as to the probable duration of the Thick coal was intended only as an approximate calculation, which he had made with as much care as he was able from the following data. For the eastern side of the district he had taken the estimates of Mr. Job Taylor, Mr. Yardley, and Mr. Cooksey, who were the best authorities as to the extent of Thick coal remaining unworked in that portion of the field, and the present rate of working there. For the rest of the district he had taken the geological ordnance map, dividing the coalfield into squares of 1 mile each, and subdividing these again into quarter miles or squares of 160 acres; and had then estimated how much of the Thick coal was left in each square from his personal knowledge of the extent to which it had been already worked. The estimate in the southern portion of the district was carried only as far as the limits to which the Thick coal had at present been proved; and therefore the calculated duration applied only to the coal north of those limits, which was now in process of working.

Mr. A. B. Cochrane thought the paper just read was a most valuable and interesting one, and the members of the Institution and the South Staffordshire district in general were greatly indebted to Mr. Mathews for the trouble he had taken in preparing it; it formed a valuable contribution to the information of the district, and he trusted it would lead to further enquiries into the subject, and improvements in the present modes of working. He fully agreed with the statements advanced in the paper, excepting in one particular, in respect to the quantity of Thick coal per acre that was raised in the district by the ordinary rib and pillar working. It was stated in the paper that the maximum quantity of Thick coal which could be raised in the first working amounted on the average throughout the district to only 16000 tons per acre, which would be increased to about 23000 tons per acre by the second working of the ribs and pillars; and that to get a greater amount it would be necessary to adopt the long wall system of working, instead of the rib and pillar working: but, though he himself had no experience of the long wall system, the result of his own experience with rib and pillar working was that a considerably greater quantity of the Thick coal than the amount named might be

raised per acre with proper care in working. He thought at least as much as 23000 tons per acre might be raised by the rib and pillar system in the first working alone, and the second working of the ribs and pillars would then yield a still further quantity. The coal must of course be of good quality to obtain such a quantity per acre, and comparatively free from faults, which interfered much with the quantity that could be raised, by preventing the coal being obtained in large peices to so great an extent, and producing a greater quantity of slack. He was inclined to think that in point of quantity of coal raised per acre the Thick coal could be worked as satisfactorily by the rib and pillar system as by the long wall mode.

As regarded the question of relative loss of life by the two systems, he quite agreed that this ought to be a primary consideration in determining the adoption of either mode of working. The long wall system appeared certainly to be attended with less danger than the rib and pillar working, both in being more secure against sudden falls of coal, and also in allowing of better ventilation of the workings. It was almost impossible to avoid accidents occurring in the rib and pillar system from the falling of masses of coal in the process of getting, and from the ribs and pillars being crushed by the weight of the roof, in consequence of the coal being of a more friable nature in some places than others: whereas in the long wall system the roof was securely propped up with a barrier of rock behind the workmen, who were thus effectually protected against falls. When an extraordinary number of faults occurred in the coal, there would be much difficulty in winning it by the long wall system; and in such portions of the district there was therefore no alternative but to work with ribs and pillars.

Mr. Job Taylor said that at New Round's Green Colliery, the only case where he had had an opportunity of obtaining the actual result of working, the quantity of Thick coal produced by the rib and pillar system amounted to 23500 tons per acre in the first working, which was rather more than the quantity given in the paper as the average produce of both workings; and in that case the coal was only from 8½ to 9 yards thick, instead of the full thickness of 10 yards. This produce was the nominal weight sold, which was about 25 per cent.

less than the actual produce, on account of the large allowance that was usual over the nominal weight. A further addition had to be made for the coal allowed to the colliers and mine owners, and the small coal consumed for the engine, besides the entire produce of the second working which had not yet been commenced; so that the total produce of the Thick coal would amount to about 30000 tons per acre. He therefore considered there was not so great a disparity in produce per acre between the two modes of working as had been represented in the paper.

From his own experience of the long wall system in other districts he did not think it was practicable for the entire seam of coal to be got even on that mode of working, as shown in the diagram: for he had found that nearly double the quantity of slack was made by the long wall working as compared with the rib and pillar, and thought it was impossible to get out the coal with safety unless a certain number of pillars were left to support the roof. In regard to risk of accidents by the long wall system as compared with the rib and pillar, he considered on the whole there were as many accidents in the long wall workings, though in a different way and probably not so frequently fatal. In undergoing the coal in the long wall system, it was liable to break down in large masses, which was avoided in the rib and pillar working where only about 2½ feet height of coal was brought down in the holing at a time; but the danger in the rib and pillar working increased as the working was carried upwards to the top coal, and the second working of the ribs and pillars was certainly attended with greater risk of accident than the long wall system. If the long wall mode of working were adopted as shown in the diagram, it did not appear that it would be interfered with by the occurrence of faults in the coal; but these would merely entail a little more caution upon the workmen to avoid the coal falling suddenly at places where they occurred.

He thought the paper gave a correct representation of the district at the present time and of the mode of working the Thick coal; it exhibited a great amount of knowledge on the subject, and showed that much time and trouble must have been spent in its preparation.

Mr. Mathews observed that in the portion of the Thick coal worked by Mr. Taylor, where so large a produce as 23500 tons per acre had been got in the first working by the rib and pillar system, the coal was of a strong quality and very rgular in its formation; so that the workings could be carried forward quickly, and a large proportion of the entire quantity of coal in the mine was obtained in the first working. Such a case was however an exceptional one, and attended with unusually fortunate circumstances. No doubt a considerably greater produce than he had mentioned was obtained in particular instances; but he thought that, taking a general practical average, it would not be possible to get more coal per acre, unless by paring down the ribs and pillars to unduly small dimensions; and after such a first working he had great doubts as to the advantage of a second working, which could only be done to profit at a time when the price of coal was high, as the marketable value of the coal obtained from the ribs and pillars would be greatly deteriorated by the heavy pressure they had supported in the first working. He had endeavoured to deal with the average production of the district, avoiding extreme cases; and there were certainly many mines in which the produce per acre fell short of the average amount. As regarded the cost of working by the two systems, there was no doubt that the rib and pillar system was the cheapest in the first working, as it did not involve the cost of erecting supports to keep the roof up as in the long wall system; but he considered the long wall was much the safer of the two, as the workmen were constantly protected by a barrier of rock erected behind them, which secured them from any risk of the roof falling in.

Mr. J. E. Swindell had worked the top measures of the Thick coal by the long wall system to a thickness of about 13 feet, which produced 12000 tons per acre, leaving pillars 4 yards square to support the roof, with intervals of 5 yards; this quantity would be increased to 15000 tons per acre by building " cogs " of rock instead of leaving pillars to keep the roof up. At present he had not worked the lower measures, but they would probably produce 11000 or 12000 tons per acre, and the total yield would therefore be about 27000 tons per acre : the middle portion of the seam, about 6 feet thickness, being left as a roof for the working of the lower measures.

Mr. Mathews remarked that the quantity of coal produced per acre by different systems of working was materially affected by its friability and general texture: for in a very friable seam of coal it might happen that the ribs and pillars would become so much crushed that they would yield only rough and fine slack, and in such a case it would not be possible to get much large coal except by the long wall system. In the Wednesbury district, where the coal was of a more hard and compact character, it stood better in the ribs and pillars, and was got in larger masses, making only a small proportion of slack.

The Chairman moved a vote of thanks to Mr. Mathews, which was passed, for his highly interesting paper, which was particularly valuable as drawn up from the results of personal experience. It formed a companion paper to that given at a former meeting by Mr. Nicholas Wood on the Newcastle coal district; and such communications were most important additions to the Proceedings of the Institution.

Mr. Mathews said he had much pleasure in preparing the paper, and considered it the duty of each of the members to contribute whatever information or experience he could, that would be of service to the Institution. In the South Staffordshire mining district it was particularly important that every endeavour should be made to reduce the great loss of life at present occurring, and to arrive if possible at a more satisfactory mode of working for obtaining the whole of the Thick coal.

The following paper was then read:—

DESCRIPTION OF A METHOD OF TAKING OFF THE WASTE GASES FROM BLAST FURNACES.

By Mr. CHARLES COCHRANE, of Middlesborough.

There is no novelty in the fact of Taking Off the Waste Gases from a blast furnace; for many methods have been and are at present employed for accomplishing this object. Though the writer was unaware of any similar method, it is not desired to claim originality in that about to be described; but as there is such acknowledged diversity of opinion as to the respective merits of different plans, and great difficulty in procuring reliable information on any, it is proposed to give a description of an arrangement which has been in successful operation for some months at the Ormesby Iron Works, Middlesborough, and bids fair to realise the best expectations of its merits. The large waste of fuel from the mouth of a blast furnace where the escaping gases are allowed to burn away is well known, and amounts to more than 50 per cent. of the fuel burnt; hence there is considerable margin for economy, bearing in mind the large quantity of coals consumed in raising steam for generating the blast and the further quantity necessary to heat that blast to the required temperature. In fact assuming a consumption of 300 tons of coke per week to make 200 tons of iron, about a 100 tons of coals would be required to generate steam and heat the blast. Taking off the gases from one furnace under such conditions does according to actual experiment furnish gas equivalent to upwards of 150 tons of coal per week. This is obviously an important matter where coals are expensive.

The blast furnace is alternately charged with coke, ironstone, and limestone, in proportions depending upon the quality or "number" of iron desired. The arrangement of these materials in the furnace is generally deemed important, though it admits of considerable latitude without any appreciable alteration in the working of the furnace.

Thus it does not seem to be of any importance whether the charge of coke be 12 cwt. or 24 cwt., the amount of load of ironstone and limestone being in the same proportion of 1 to 2. The chief point, if there be one, to be gained in the arrangement of the material is to distribute it pretty equally over the furnace, not allowing all the large material to roll outwards and the small to occupy the centre of the furnace or *vice versâ:* for it is supposed the ascending gases will pass through the more open material of the furnace to the injury of the closer; thus the two reach the active region of reduction in different states of preparation, and the operations of the furnace are interfered with. To provide for this contingency, which is met in an open-topped furnace by filling at the sides at three, four, or even six points of the circumference of the throat, allowing the material to slide inwards 2 or 3 feet on a sloping plate, it was considered expedient in the present instance to make the filling aperture as large as practicable: it was therefore made 6 feet 6 inches diameter, as shown in Fig. 1, Plate 24, so that the material tends to arrange itself in a circle a little outside the centre, thus correcting the tendency of large material to roll outwards by causing a similar tendency to roll towards the centre also. This point is gained in one of the simplest methods in use for closing the top of a blast furnace, where a cone is used to lower into the furnace for filling; but it is secured at the expense of the height of material in the furnace. A certain height is necessary for the efficient working of the furnace, and if this be diminished it must be at the expense of fuel in the furnace, since the absorption of heat from the gases depends on the height of material through which they have to pass up: if this be diminished, the gases issuing from the throat of the furnace will escape at a higher temperature; if increased, at a lower.

But there is an important difference to consider in the conditions of a closed and an open-topped furnace, to which the writer is not aware that attention has hitherto been drawn; a difference which acts somewhat in favour of the open-topped furnace. The working of the furnaces themselves seems to show that an open-topped furnace is less sensitive to irregularities of moisture in the material, quantity of limestone, size of material, &c.; which can be accounted for only by

the fact that the open-topped furnace has the advantage of a large amount of surplus heat due to the combustion of the waste gases at its throat, which serves to dispel moisture and calcine the limestone and helps to warm up the large pieces of ironstone: all of which operations in the close-topped furnace are effected only at a lower point of the furnace, thus necessitating a large consumption of coke. With the same proportion of ironestone to limestone it has been found to require about 10 per cent. more fuel to produce the same number or quality of iron in a close-topped than in an open-topped furnace. In the close-topped furnace the gases pass away at a temperature of about 450° Fahr.; whilst in the open-topped a temperature of between 1000° and 2000° is generated in the throat of the furnace by their combustion.

In comparing the extra quantity of coke consumed in a close-topped blast furnace with the saving in coals for the boilers and hot-blast stoves, it is obvious that the economy to be derived by taking the gases off depends on the comparative value of coke and coal. In the Middlesborough district where coal is expensive, it is an undoubted source of economy; where coke is very dear however and small coal can be obtained at a mere nominal cost for boiler and stove purposes, the use of the waste gases would possibly do little more than compensate for the outlay involved. Here no doubt is one source of the variety of opinion entertained in various districts as to the advantage of taking off the gas. The writer's experience at Middlesborough has been that the waste gases can be taken off without affecting the quality of the iron produced, though at the expense of more fuel.

The mode of closing the furnace top and taking off the gases at the writer's works is shown in Fig. 1, Plate 24. The top of the furnace is closed by a light circular wrought iron valve A, 6 feet 6 inches diameter, with sides tapering slightly outwards from below, as shown enlarged in Fig. 2, Plate 25, to admit of being easily drawn up through the materials, which are tipped at each charge into the external space B. To prevent excessive wear upon the body of the valve, shield plates are attached at four points of its circumference,

against which the material strikes as it rolls out of the barrows. An annular chamber C encircles the throat, triangular in section, into which the gas pours through the eight orifices D D from the interior of the furnace, and thence passes along the rectangular tube E into the chamber F. At the extremity of the tube E is placed an ordinary flap valve opened by a chain, by means of which the communication between the furnace and the descending gas main G may be closed. The valve A is partially counterpoised by the balance weight at the other extremity of the lever H, and is opened by a winch I when the space B is sufficiently full of materials. At the time when the blast is shut off for tapping the furnace, the gas escapes direct into the atmosphere through the ventilating tube K, which is connected by levers L with the blast inlet valve below.

Fig. 5, Plate 26, shows the connexion between the furnace top and the hot-blast stoves to be heated by the waste gases, which pass down the descending main G into the horizontal main M running parallel and close to the line of stoves N, from which descend smaller pipes O to each stove, as shown in Figs. 3 and 4. The supply of air for burning the gas in the stoves is admitted through the three tubes P, and can be regulated at pleasure by the circular slide closing the ends of the tubes, which has an apperture corresponding to each tube, and is planed on the rubbing face, as is also the surface against which it works, in order that the slide may be sufficiently air-tight when closed. The ignition takes place where the air and gas meet, the ignited gas streaming into the stove and diffusing its heat uniformly over the interior. An important element in the working of an apparatus of this description is to provide for explosions, which must take place if a mixture of gas and air in certain proportions is ignited. To provide for this contingency, escape valves R are placed at the ends and along the tops of the main tubes G and M: but to prevent explosions as far as possible, the ventilating tube K, Fig. 1, is used at the top of the furnace, connected with the blast valve at the bottom so that when the valve is closed, as at casting time, the act of closing opens the ventilating tube and allows the gas to pass away direct into the atmosphere. The gas would otherwise be in danger of slowly mixing with air passing back through the stoves or otherwise gaining

access into the tubes, and would thus give rise to an explosion; until the ventilating tube was provided, it was necessary to lift the valve A closing the mouth of the furnace when the blast was taken off, otherwise slight explosions took place from time to time.

In the use of Durham cokes in the blast furnace an inconvenience arises from the large deposit which takes place in the passage of the gas from the furnace and in the stoves and boilers. Under the boilers this deposit is a great objection, as it is a very bad conductor of heat and needs to be frequently removed: in the stoves it is not so objectionable, though these need a periodical cleansing. The deposit does not arise altogether from the cokes, it is true; and it may be interesting to know its composition which is as follows:—

Silica	18.86
Carbon	16·14
Alumina	13·87
Sulphate of Lime	13·61
Lime	11·01
Protoxide of Zinc	10·31
Peroxide of Iron	9·01
Protoxide of Manganese	2·56
Potash	2·13
Protoxide of Iron	1·25
Magnesia	1·25
Chloride of Sodium	0·60
	100·60

At a temperature of upwards of 3000° this mixture melts in a yellowish slag, dispelling the zinc; but there are no signs of fusion at the temperature produced by the ignition of the gas in the stoves, which must roughly approximate to that of melting iron from the results of a few experiments made to ascertain this point: though thin pieces of cast iron were not fairly melted down, they reached the rotten temperature, which is only a few degrees below melting, and gave further signs of nearly melting by throwing off sparks when quickly withdrawn from the stoves and struck smartly against another object.

The writer has heard it asserted that the closing of the top of the furnace is the source of mischief to its working by producing a back pressure in it. Under ordinary circumstances, with the furnace top open, the blast enters the tuyeres at a pressure ranging from $2\frac{1}{2}$ to 3 lbs. per square inch. In the present close-topped furnace there are eight outlet orifices D, Fig. 1, each 2 feet by 1 foot, giving a total area of 16 square feet for the passage of between 5000 and 6000 cubic feet of gas per minute raised to a temperature of 450° Fahr.; and the actual back pressure of the gas as measured by a water gauge inserted into the closed top of furnace is from $\frac{1}{2}$ to $\frac{5}{8}$ inch column of water, or about 1-40th or 1-50th of a pound per square inch, an amount so trivial as compared with a pressure of from $2\frac{1}{2}$ to 3 lbs. as to be unworthy of notice. Of course if the tubes are contracted in size a greater back pressure will be produced; and it is quite possible that, where attention has not been paid to the circumstance, the back pressure may have interfered with the working of the furnace by preventing the blast entering so freely.

As regards economy in the wear and tear of hot-blast stoves of the ordinary construction, there can be no question the pipes last much longer when heated by gas, provided the temperature of the stove be carefully watched to prevent its rising too high; whilst the value of the same heating surface compared with its value when coals are used is greatly increased, owing to the uniform distribution of the ignited gases throughout the stove: in the use of the gases at the writer's works, this economy of surface is such that two stoves heated by gas will do the work of a little more than three heated by coal fires.

Mr. W. Mathews considered the subject of economising the waste gases from blast furnaces was one of much importance, and was glad it had been so ably taken up in the paper just read. He asked whether there was found to be any material difference in the working of the close-topped furnace, and whether the closing of the top for

the purpose of taking off the gases interfered with the burden of the furnace or the quality of iron produced. If the quality and yield of iron were not disturbed, the utilisation of the waste gases must be a source of economy where fuel was dear; but otherwise, where coals were cheap, it might hardly be worth while putting up an apparatus for taking off the gases. In the case of some blast furnaces lately erected at Heyford in Northamptonshire, where the ore was cheap but coal expensive, costing 14*s*. or 15*s*. per ton at the furnaces, the iron could not have been worked profitably unless the waste gases were taken off; this had accordingly been done, and he understood had proved thoroughly successful, reducing the cost of making the iron greatly. It seemed remarkable that the use of the waste gases was not yet adopted in South Staffordshire; but this was no doubt owing to the extreme cheapness of small coal throughout the district, as compared with the North of England, so that it might not be economical to take off the gases. At Dundyvan in Scotland a method had been employed some years ago for taking off the gases without closing the top of the furnace, and the gases were used for the hot-blast ovens and engine boilers: but the heat obtained was very irregular, sometimes high and sometimes low, causing much difficulty in keeping up the temperature of blast and in getting the required supply of steam; and he understood the plan had recently been discontinued there on account of the trouble experienced in its use.

Mr. C. Cochrane replied that the regularity of the furnace was certainly interfered with, though only to a slight extent, by closing the top, and the furnace was rendered more sensitive. In the first trials of the close-topped furnace mottled iron was made frequently, and occasionally white iron; but by exercising sufficient care in managing the furnace the irregularities were now in a great measure got over. During the last six months his furnace had worked with only 7 per cent. irregularity altogether, and this was now reduced to 5 per cent., estimating the amount of irregularity by the proportion of mottled iron made instead of grey. Where it would be an objection to make mottled or white iron occasionally, it would not be advisable to try taking off the gases; and coals were so cheap in South Staffordshire that it might not be worth while to run the risk of getting white

iron, as it was of more importance there to make all grey iron than in the Middlesborough district, where there was a greater demand for forge iron.

Mr. C. Markham had been connected with some blast furnaces at Marquise in the north of France fourteen years ago, from which the waste gases were taken off very successfully; and thought the mode of carrying out the plan in that case was superior, owing to the gases being conveyed upwards to a higher level to be burnt, as they would naturally rise by reason of their specific gravity being less than that of the atmosphere. There were two furnaces built side by side against a bank, and the gases were taken off about 5 or 6 feet below the top by a circular flue running all round the furnace; they were taken under six Cornish boilers situated at the top of the bank, a few feet above the top of the furnace. The gases were drawn off from the furnaces by a chimney 90 feet high, and they frequently produced a large flame from the top of the chimney. The evil of the gases firing subsequently to passing under the boilers was removed to a considerable extent by the erection of an additional flue, which caused the gases to be more perfectly mixed with air and fired before they were cooled down by coming in contact with the boilers. The regular make of each furnace was 100 to 120 tons of cold-blast iron per week, and the consumption of coke was about 1½ tons per ton of iron made. The coke cost 30*s.* per ton, so that economy of fuel was of great importance; the boilers were worked entirely by the waste gases from the furnaces. At these furnaces they had tried at first bringing the gases downwards to the boilers at a lower level, but the success was very imperfect; and this appeared to him the reason why the waste gases had not been taken off so successfully at some works in this country, as they had in every case he believed been conveyed downwards from the top of the furnace instead of upwards, and also the height of the furnace had not been increased to compensate for the gases being taken off at a lower level. He had seen the application of the gas at the Clay Cross and Alfreton furnaces in Derbyshire, and had no doubt an economy was effected in the cost of the iron made: at these works however the gas was applied only for heating the hot-blast stoves, but the quantity required to heat the blast was small as

compared with that required to raise a sufficient supply of steam for working the blast engine.

Mr. C. COCHRANE said no difficulty had been experienced in bringing the gases down, and the vacuum required was found by actual measurement to be only $\frac{1}{2}$ to $\frac{5}{8}$ inch column of water, or 1-40th lb. per square inch, which was not sufficient to produce any injurious effect on the working of the furnace.

Mr. C. W. SIEMENS had seen furnaces working at Charleroi in Belgium where the gases were drawn down from the top of the furnace without any difficulty, by means of a pipe inserted in the side of the furnace near the top; but it was found necessary to allow at least one-third of the gas to burn out of the mouth of the furnace, otherwise the working of the furnace was interfered with, and neither was the iron of such good quality nor the gas so effective for heating purposes. In the close-topped furnace at Middlesborough described in the paper he suggested whether any difference of make or irregularity of working was not rather to be attributed to imperfect distribution of the materials in charging, than to closing the top; with a closed top and an arrangement for filling in the centre, as shown in the drawings, there was no means of filling at the sides of the furnace, and the materials might roll sometimes more to one side than the other, producing a greater draught through the furnace in one direction, so that the ore would arrive at the point of reduction in different states of preparation, which would interfere with the quality of iron made. A slight difference was sufficient to direct the flame and current of gas in a blast furnace more to one side than another: even in drawing off the gases by a circular chamber all round the furnace, the draught holes on the side nearest the main flue would draw more than those on the opposite side; but this might be obviated by making the holes nearest the flue of a samller size.

Mr. SAMUEL LLOYD said they had now adopted a plan for taking off the waste gases at the Old Park furnaces, and had had it working there successfully for some weeks, without any injury being caused to the working of the furnace; the iron seemed if anything to be rather better in quality, a little more grey, and somewhat increased in quantity. The plan was that of Mr. Darby of Brymbo in North Wales, where it

had been at work successfully for two years past; it consisted of a plain upright tube inserted into the centre of the open mouth of the furnace, and then carried over down the outside of the furnace, where the gas was burned under the steam boilers, the flues of which were connected with a sufficiently tall chimney to produce a draught for drawing down the gas. The large area between the tube of 5 feet diameter and the mouth of the furnace of 10 feet diameter was left open, so that there was no pressure on the furnace, which worked in that respect exactly like an open-topped furnace. The tube was inserted about 5 feet deep into the materials at the top of the furnace, and by this means they got four boilers heated by gas without any cost for fuel. He thought this plan of leaving a large portion of the furnace top open was the only practicable way of taking off the waste gases in the South Staffordshire district, where it was of the first importance that grey iron should be made, and considered it was a great improvement on the close-topped system: for the open top of the furnace allowed the extra quantity of gas to escape direct into the atmosphere; but with a closed top the top of the furnace was choked, and the accumulation of gas was liable to produce a back pressure on the furnace, which they had found by experience was very injurious.

Mr. E. A. Cowper had seen the furnace at the Ormesby Works, and thought the arrangement there employed for filling produced a good distribution of the materials. The plan of closing the furnace top by a cast iron cone or bell inside the furnace, fitting up against a cast iron ring or seat, was a good arrangement when properly carried out, as at Ebbw Vale; though in some cases, where the cone had not been properly proportioned to the size of the furnace, an unequal distribution of the materials took place, the smaller pieces lying in a heap in the centre, while the larger ones rolled down to the sides of the furnace, causing a stronger draught up the sides than at the centre; and in large-topped furnaces where the charging cone was of small size, the sides thus became much hotter than the middle of the furnace. But in the arrangement shown in the drawings this difficulty was got over by making the charging opening not less than half the diameter of the top of the furnace, the effect of which was that the larger pieces now rolled towards the centre as well as the

sides, so that there was as strong a draught up the centre as at the sides, and the heat was rendered more uniform. He believed that the regular working of a furnace depended quite as much upon the materials being nearly of a uniform small size as on anything else, and that sufficient attention was not generally given to this point. The simple fact of closing the top of the furnace or leaving it open could not he thought cause any appreciable difference in the working of the furnace; for the ordinary pressure of the atmosphere on an open-topped furnace varied far more than the increase of pressure caused by closing the top and drawing off the gas by the draught of a chimney, as this was shown to amount to only $\frac{1}{2}$ inch column of water, or only 1-24th inch rise of the barometer. If a closed top were inadmissible for a furnace from some other cause, then such a plan as Mr. Darby's might be adopted for taking off a portion of the gas; but a high chimney would be necessary to draw the gas off through the tube, and care must be taken to keep the mouth of the tube always covered up for some depth by the material in the furnace, to prevent the risk of drawing in atmospheric air; the tube would he thought be troublesome to keep in repair on account of the great heat to which it was exposed, and with its end buried 5 feet deep in the material would not last many weeks.

Mr. A. B. Cochrane was glad to hear of an instance of the waste gases being taken off successfully in the South Staffordshire district, as their use would effect an important saving of fuel for the steam boilers and hot-blast ovens, if it could be satisfactorily carried out; for though at present there was an abundance of cheap small coal, it had been pointed out that the time was drawing near when the Thick coal would be exhausted in the parts now worked, and it was therefore as necessary to economise the consumption in that district as in the North of England. He hoped the plan that had been referred to would be described more fully, with the results obtained as to cost and economy of fuel, that it might be satisfactorily determined whether such a method was applicable without injury to the quality of iron made.

Mr. J. E. Swindell asked what distance the gases could be conveyed from the furnace for being burnt for heating purposes.

Mr. E. A. Cowper replied that the gases could be carried a great distance, several hundred yards even, before being burnt, as the slight pressure in the top of the furnace was quite sufficient. When taken off from a close-topped furnace, they came off at a comparatively low temperature of about 400°, and would lose only 50° to 100° within moderate distances.

Mr. Sampson Lloyd had tried the plan of taking off the gases by a closed top and charging cone several years ago at the Old Park furnaces, on the method adopted in South Wales that had been mentioned, but it was finally abandoned, as the furnace could not be got to work satisfactorily; and they were about to take down the pipes used for conveying away the gases, when he heard of the plan employed at the Brymbo Works, which seemed fully to meet the difficulty of avoiding any interference with the working of the furnace, and an apparatus of that kind was accordingly put up. They had several difficulties to encounter in the first attempts at getting the plan to work; and the end of the tube was melted off in consequence of reaching too far down into the hot part of the furnace. But all objections seemed now to have been got over, and they had had the plan at work nearly a month with most satisfactory results: the furnace worked better, and brought down the iron more quickly; it only required a little management when standing, to prevent the portion of the tube in the furnace getting injured.

Mr. C. Markham observed that there must be still a great waste of gas escaping through the open space round the centre tube, when the top of the furnace was not entirely closed. Even in close-topped furnaces fitted with a cone a considerable leakage of gas took place round the joint of the cone, and when the furnace was being charged; and in the arrangement shown in the drawing he thought the leakage at the joint would be much increased by the large diameter of the top valve.

Mr. E. A. Cowper said the valve had a very good joint, as it was made with a cast iron rim at the bottom, having a spherical bearing surface, so as to drop always fairly into its seat like a ball valve, and the seat was a strong cast iron ring, to ensure keeping its shape; the valve closed remarkably tight when lowered into its seat, scarcely a trace of leakage being perceptible at the joint.

Mr. T. Snowdon thought in working with close-topped furnaces for taking off the gases a great deal depended on having a sufficient height of chimney to ensure drawing off the gas with regularity; if the chimney were only as high as the furnace, the two columns of gas would balance each other and there would be no power of draught. The draught required however seemed to vary much in different furnaces; for in the Clay Lane furnaces at Eston near Middlesborough the chimney was only a few feet above the top of the furnace, but produced quite draught enouch, while he had seen other furnaces with higher chimneys that were not working well. At his own furnaces at Middlesborough he would have preferred placing the boilers and hot-blast stoves at the top of the furnace if it could have been done, in order to take the gases direct to them; but this was not practicable, and the gases were therefore drawn down from the top of the furnace by a chimney 120 feet high and 8 feet square, having 64 square feet area of draught. The temperature and nature of the gases taken off depended greatly on the burden of the furnace, according to the quality of ironstone that was being worked: with a heavy charge of limestone the gas would not burn without great difficulty, owing to the carbonic acid gas mixed with it; and he had noticed that when the gases were best for burning, the temperature was so low in the top of the furnace that the materials were quite damp, and a long rod thrust in was drawn out covered with moisture. The gases ought never to be taken off hot through the tubes, if it could be avoided; and at Valenciennes in France some of the best working furnaces he had seen were quite cool at the top, the gases being entirely taken off and the tops closed. He was so confident of the practicability of using the waste gases that no provision had been made for a fire in the hot-blast stoves at his own works, intending to use gas entirely for heating them; but they had to put in a fire at first on starting the furnaces, though it was now used very little, and mainly at the time of starting. Some of the boilers were working without any coal fire, being heated entirely by gas; and the total quantity of coal used both for boilers and hot-blast stoves was less than 1½ cwt. per ton of iron made: the coal was a mixture of small coal and slack, costing only 4*s.* per ton. The use of gas saved the attendance of men for firing under the boilers and stoves.

Mr. C. COCHRANE enquired what amount of irregularity had been experienced in the working of the close-topped furnaces At the Ormesby Works he had found that for making the same quality of iron only 7 per cent. more coke was required during six months with the close-topped furnace than had previously been consumed in the same furnace before the gas apparatus was employed. But under the best circumstances irregularities would occur, arising sometimes from the level of the materials in the furnace being allowed to go down a few feet, from want of attention in charging, so that the materials did not get so thoroughly prepared before sinking to the point of reduction in the furnace; and there was more liability of this occurring in close-topped furnaces than in open ones, from the difficulty of seeing in to observe the level. He had found his furnaces would sometimes turn round suddenly to white iron for a short time, and then return to grey iron; this was not of much consequence in the North of England, where white or mottled iron could easily be disposed of, but that was not the case in South Staffordshire.

Mr. T. SNOWDON replied that change of weather and difference in the ironstone were the chief causes of fluctuations in the quality of iron and yield of the furnace; but he could not say that any material irregularity had resulted from taking off the gases. The iron produced from the close-topped furnaces appeared rather superior in quality, darker and with larger crystals; and he had never found the furnace drop off from grey iron to mottled or white. In close-topped furnaces the materials at the top were not exposed to differences of dry or wet weather as in open-topped furnaces; his own furnaces had the top closed by a cylinder and charging cone, like that at Ebbw Vale, and were charged with a whole wagon load of 36 cwts. at once tipped direct into the furnace, so that there was no irregularity in filling, and a saving of labour compared with charging by barrows.

Mr. D. ADAMSON observed that if there were much variation in the temperature of the gases coming off from the furnace it would affect the draught produced by the chimney, and so might influence the working of the furnace: for when the furnace was so cool at the top as to be damp, the chimney would cause an increased draught and augment the current through the furnace; while a high temperature of

the gases in the top of the furnace would partly counterbalance the heated column in the chimney and the draught would be diminished. Care should be taken to have the firegrates under the boilers and stoves closed air-tight, to prevent any air entering to impair the draught; and also to have a sufficiently high chimney to avoid any pressure of gas in the closed top of the furnace. If the chimney were large enough he could not see any reason why closing the top and taking off the gases should interfere with the proper working of the furnaee; and thought there would even be an advantage in a close-topped furnace, by the pressure being relieved below that of the atmosphere, ensuring a more active condition in the furnace under all circumstances.

The CHAIRMAN proposed a vote of thanks to Mr. Cochrane for his paper, which was passed.

The following paper was then read :—

INDIA-RUBBER COVERING MACHINE.

Fig 1.
Side Elevation.

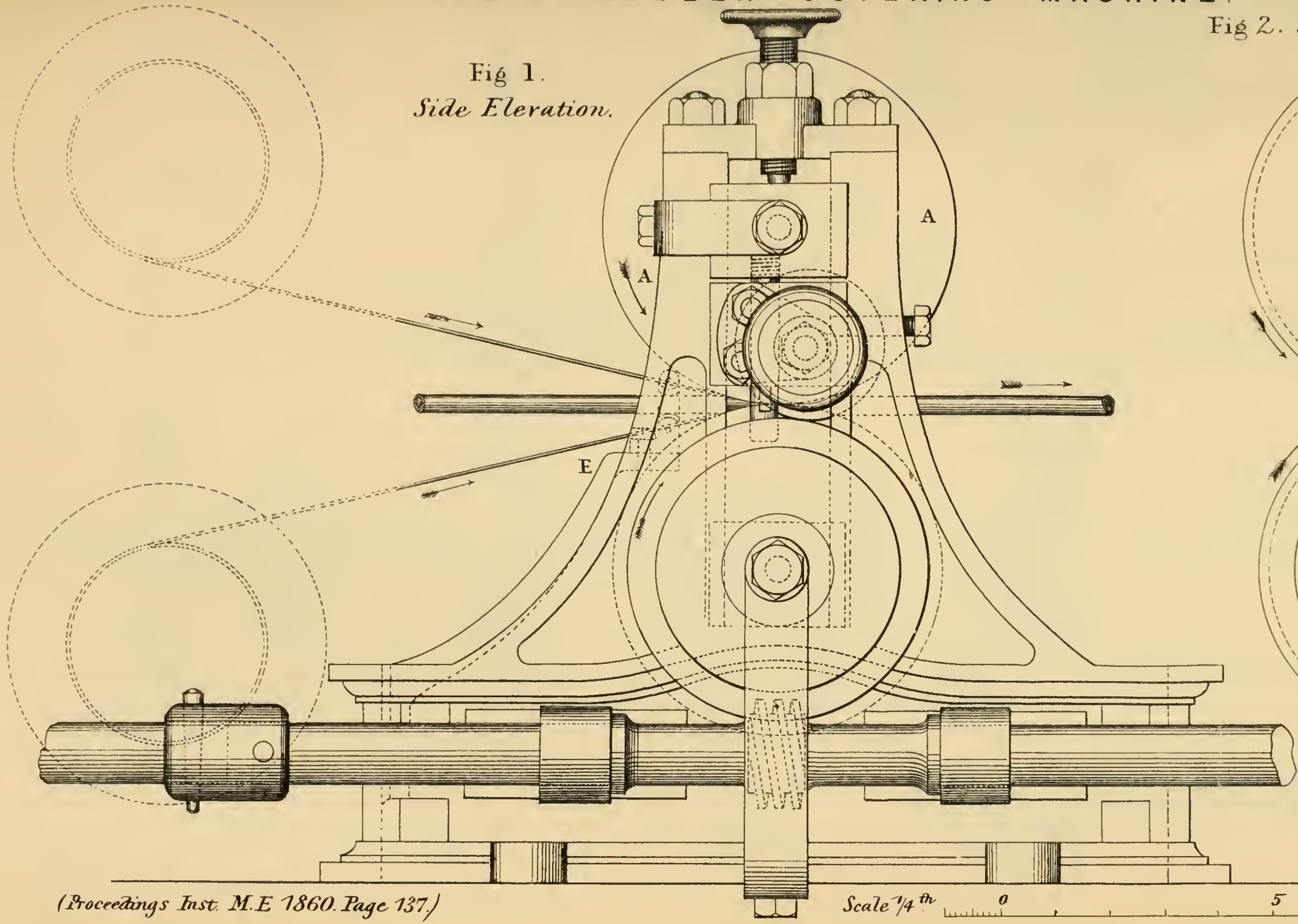


Fig 2. *Side Elevation of Rollers.*

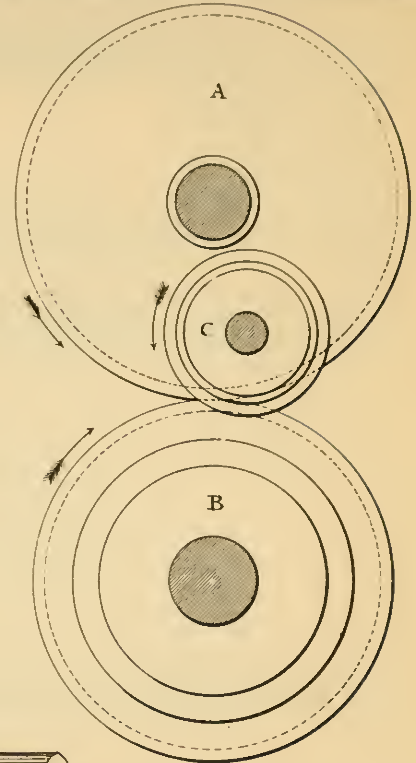


Plate 27

Scale 1/4th 0 5 10 Ins.

(Proceedings Inst. M.E. 1860. Page 137.)

INDIA – RUBBER COVERING MACHINE.

Fig 3.
End Elevation partly Section.
Scale ¼th.

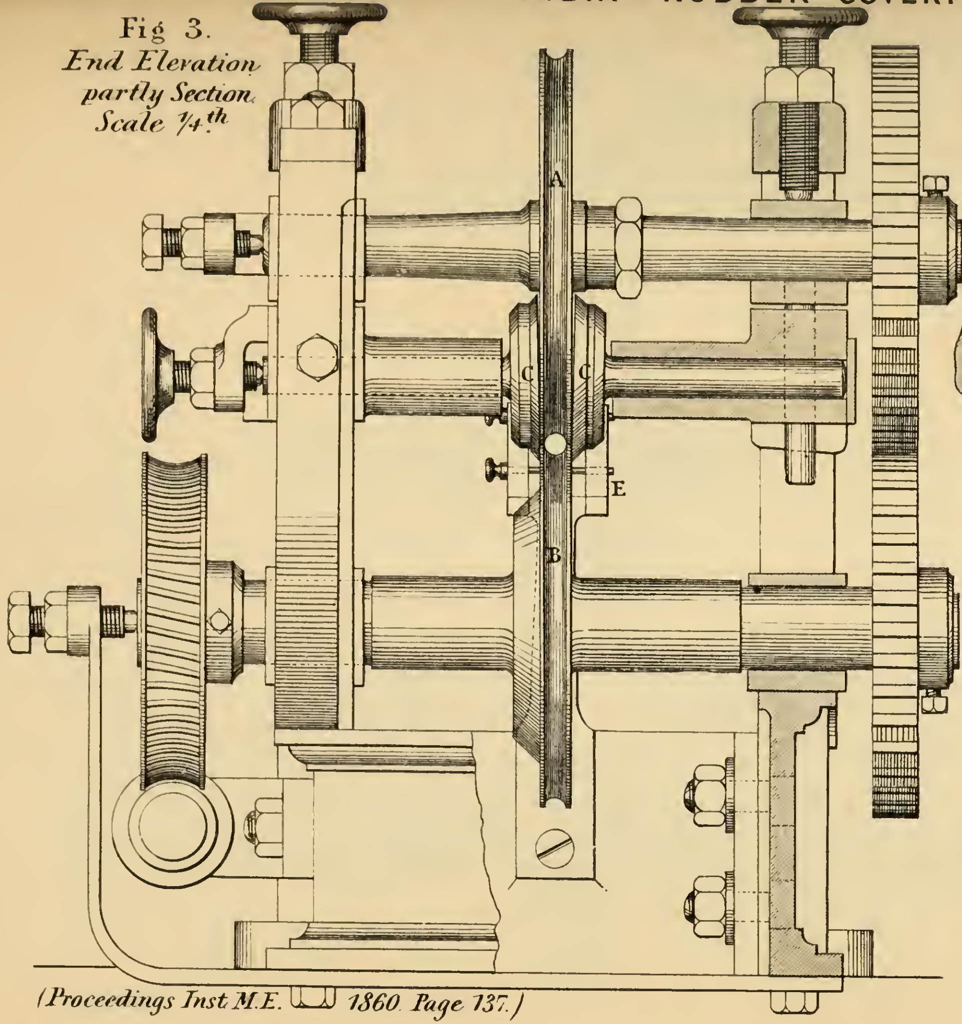


Fig 4.
Vertical Section enlarged.
Scale ½ full size.

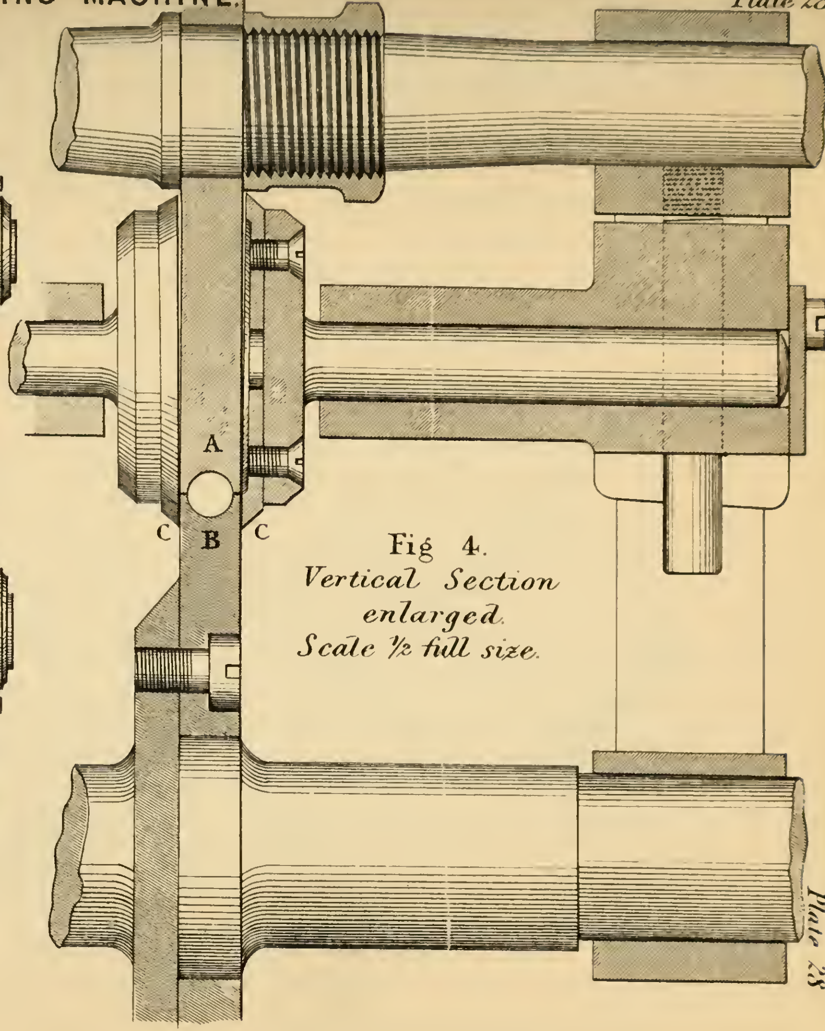
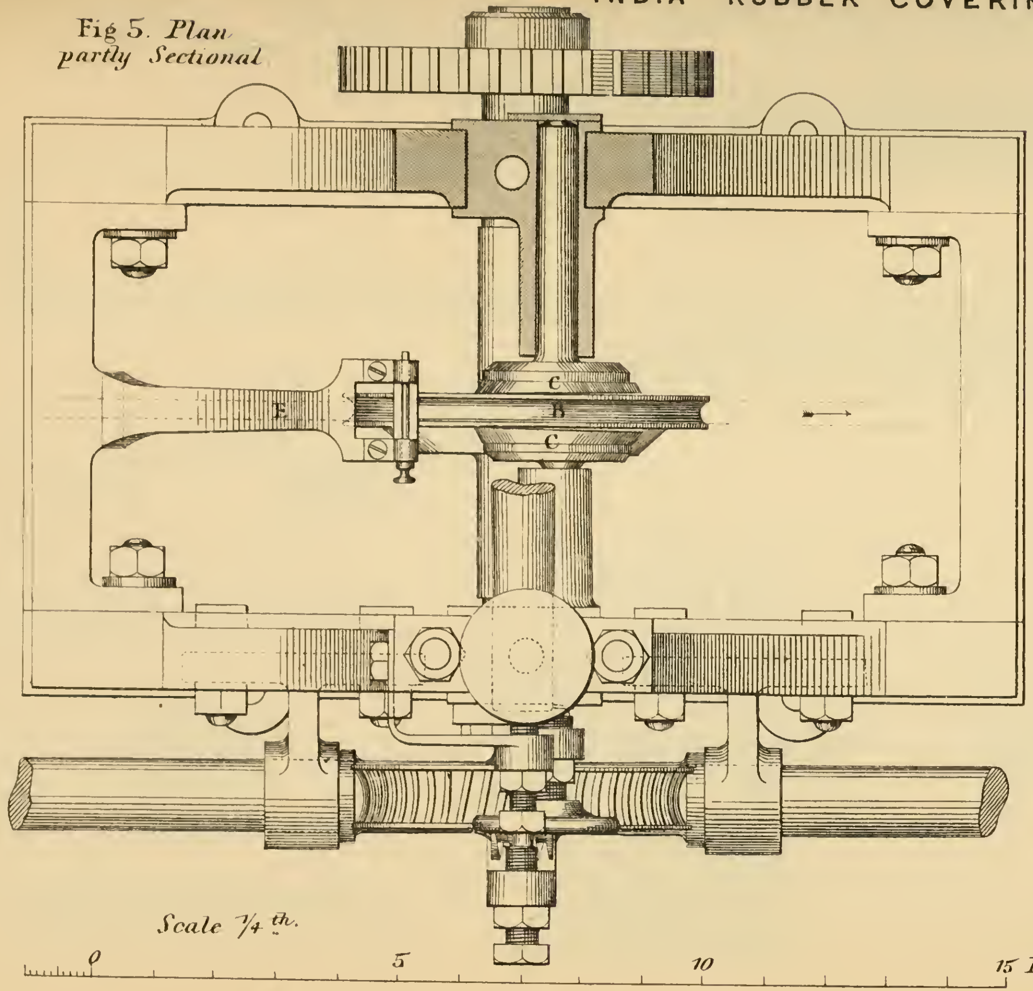


Plate 28

INDIA-RUBBER COVERING MACHINE.

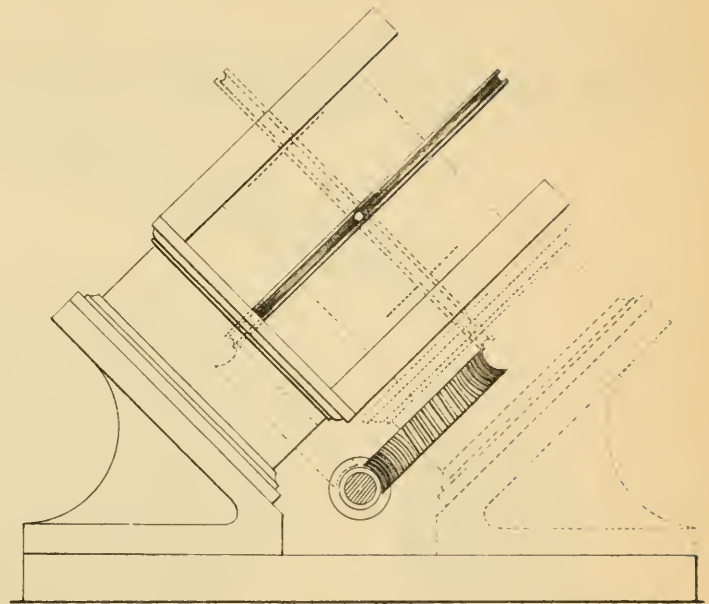
Fig 5. *Plan partly Sectional*



Scale ¼th.

Fig 6.

General Arrangement of Train of Machines.



Scale ⅛th

(Proceedings Inst. M.E. 1860 Page 137.)

Plate 29

INDIA-RUBBER COVERING MACHINE.

Fig 7. *Longitudinal Section through Pressing Rollers.*

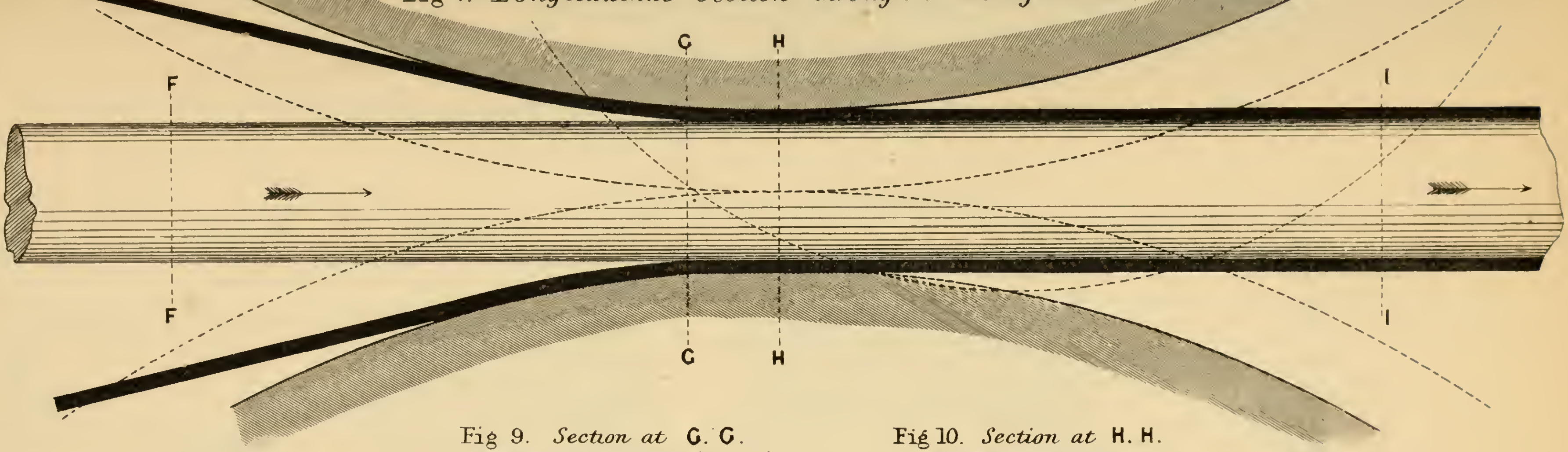


Fig 8. *Section at* F. F.

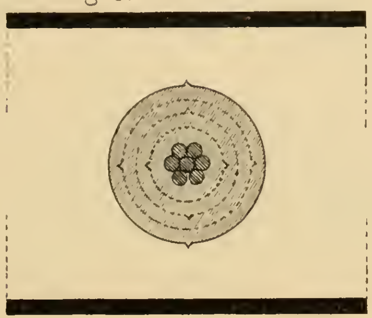


Fig 9. *Section at* G. G.

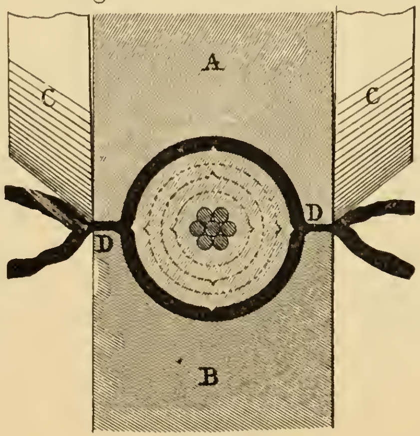


Fig 10. *Section at* H. H.

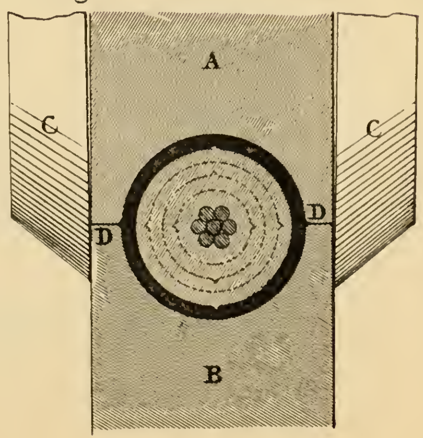
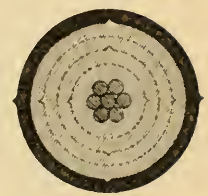


Fig 11
Section at II.



Scale double full size.

(Proceedings Inst. M.E. 1860 Page 137.)

Plate 30.

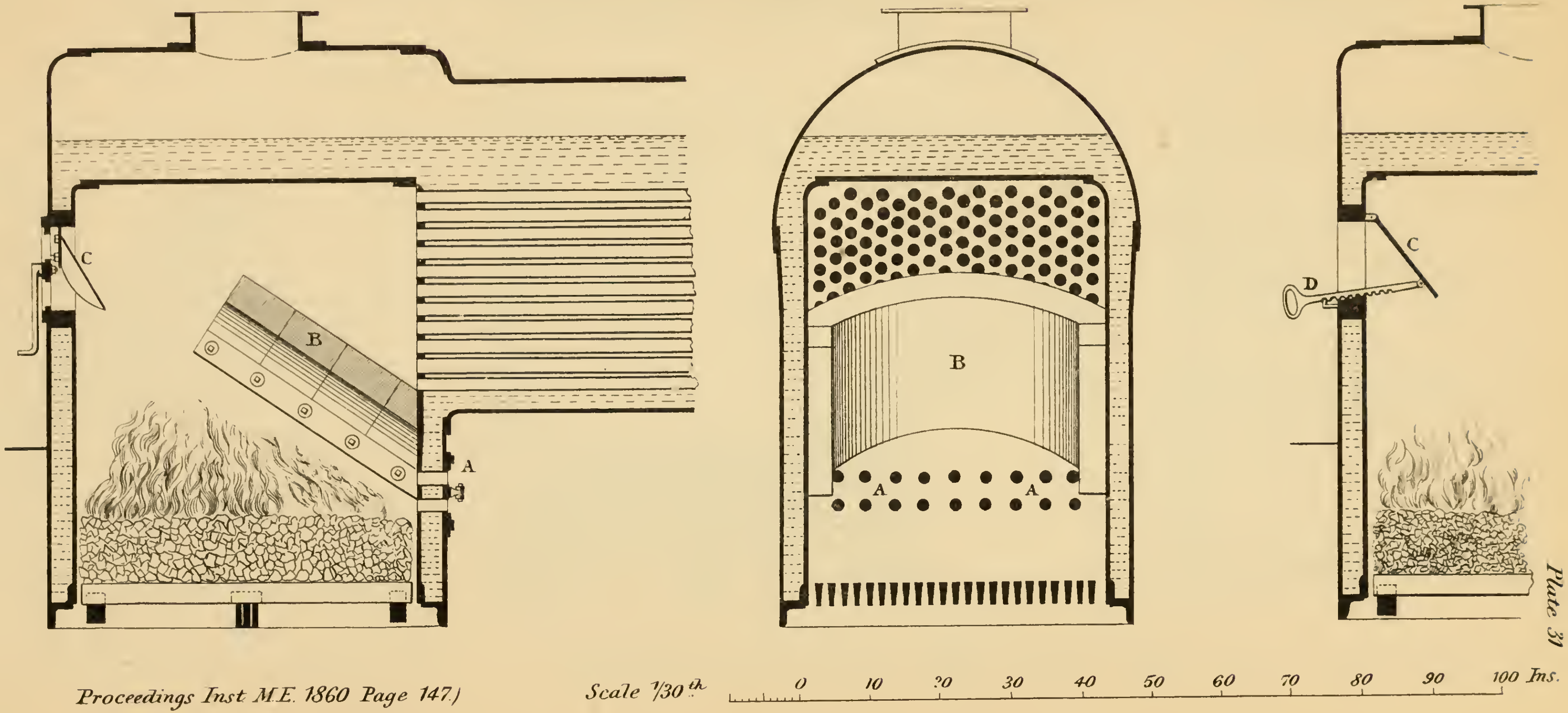
COAL BURNING IN LOCOMOTIVES.

Firebox with Air Holes, Brick Arch, and Deflecting Plate.

Fig 1. *Longitudinal Section.*

Fig 2. *Transverse Section*

Fig 3. *Firebox with Hinged Deflecting Plate.*



Scale 1/30th

COAL BURNING IN LOCOMOTIVES.

Firebox with Firebrick Bars, Deflecting Plate, and Air Holes.

Fig. 4. *Back Elevation.*

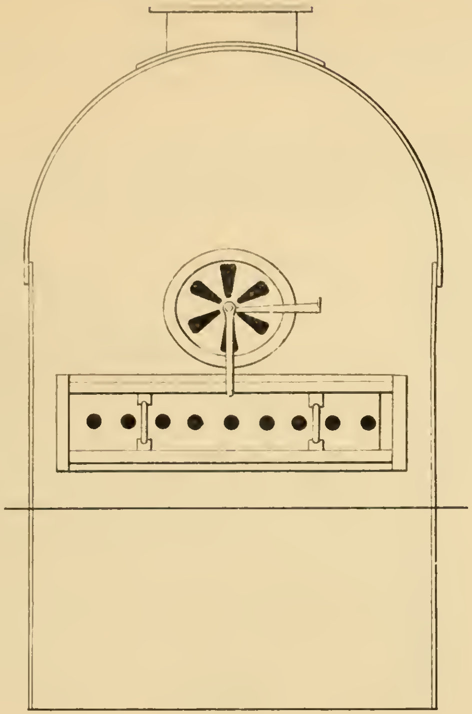


Fig. 5. *Longitudinal Section.*

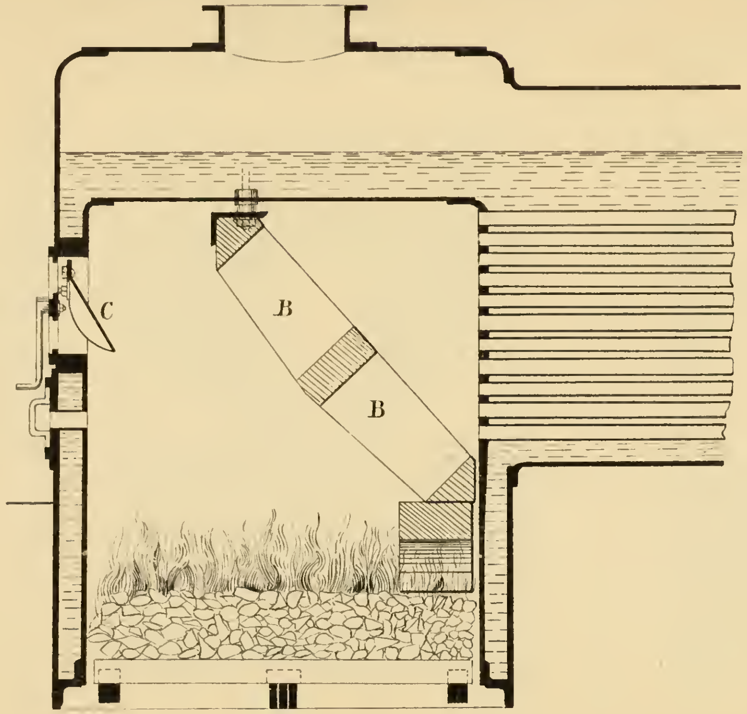
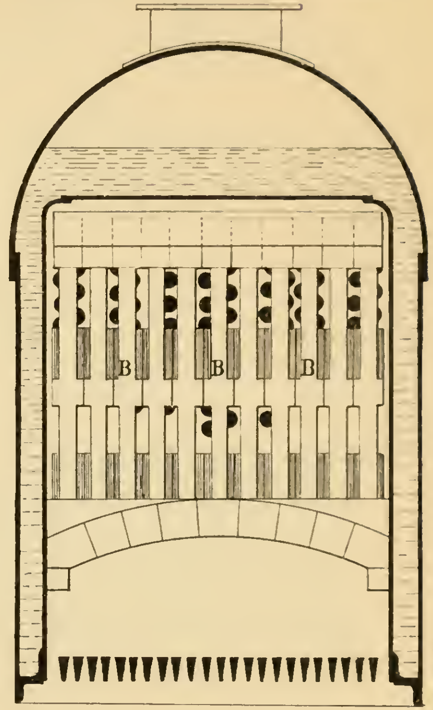


Fig. 6. *Transverse Section.*



Scale 1/30th. 0 10 20 30 40 50 60 70 80 90 100 ins.

Plate 32.

COAL BURNING IN LOCOMOTIVES.

Firebox with long Deflecting Plate, Present Arrangement.

Fig. 7. *Longitudinal Section.*

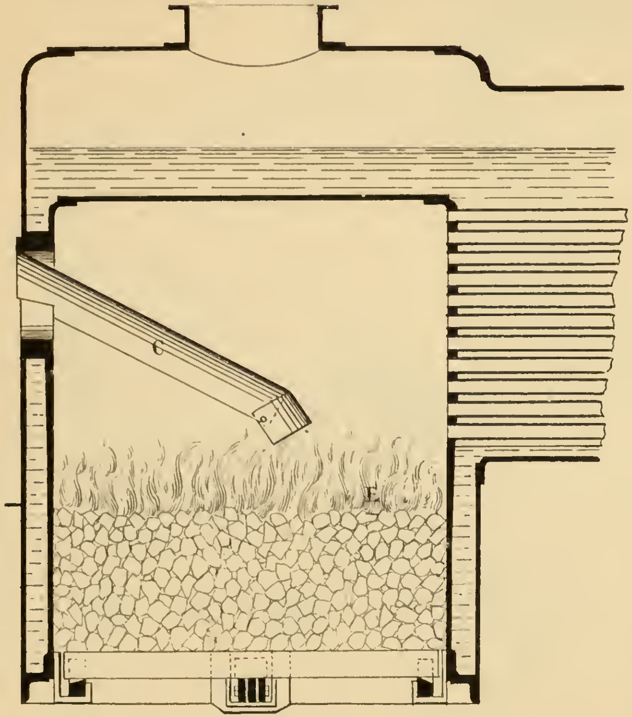


Fig. 8. *Transverse Section*

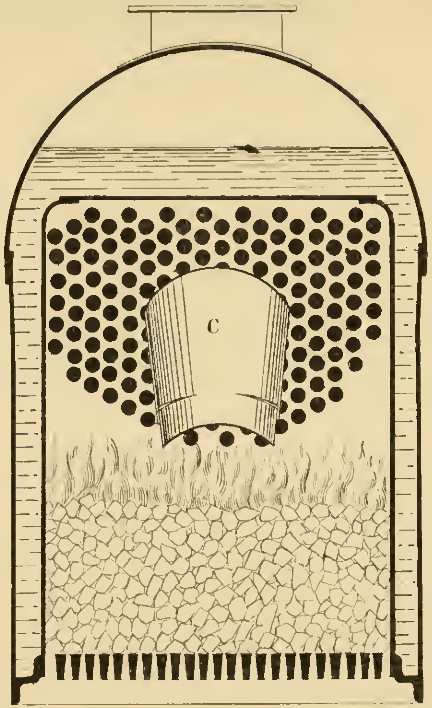


Fig 9. *Mudfeather Firebox with Deflecting Plate*

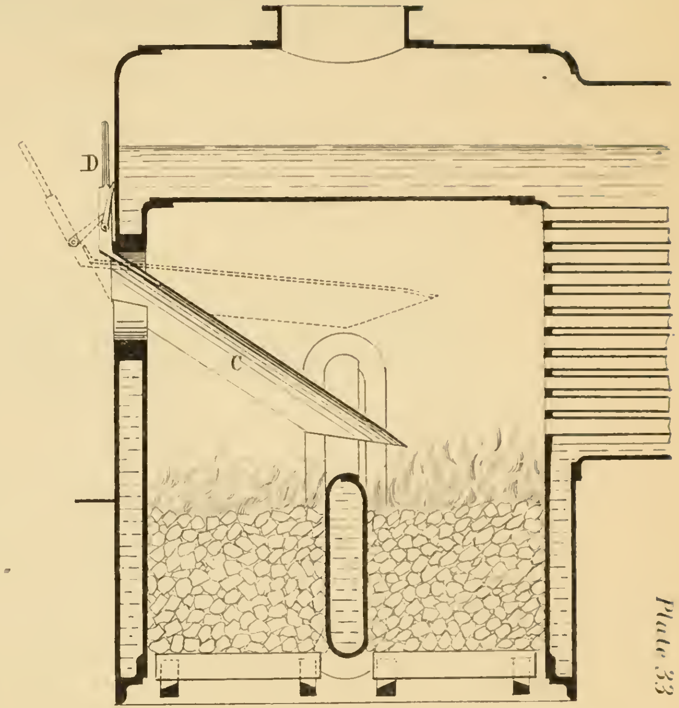


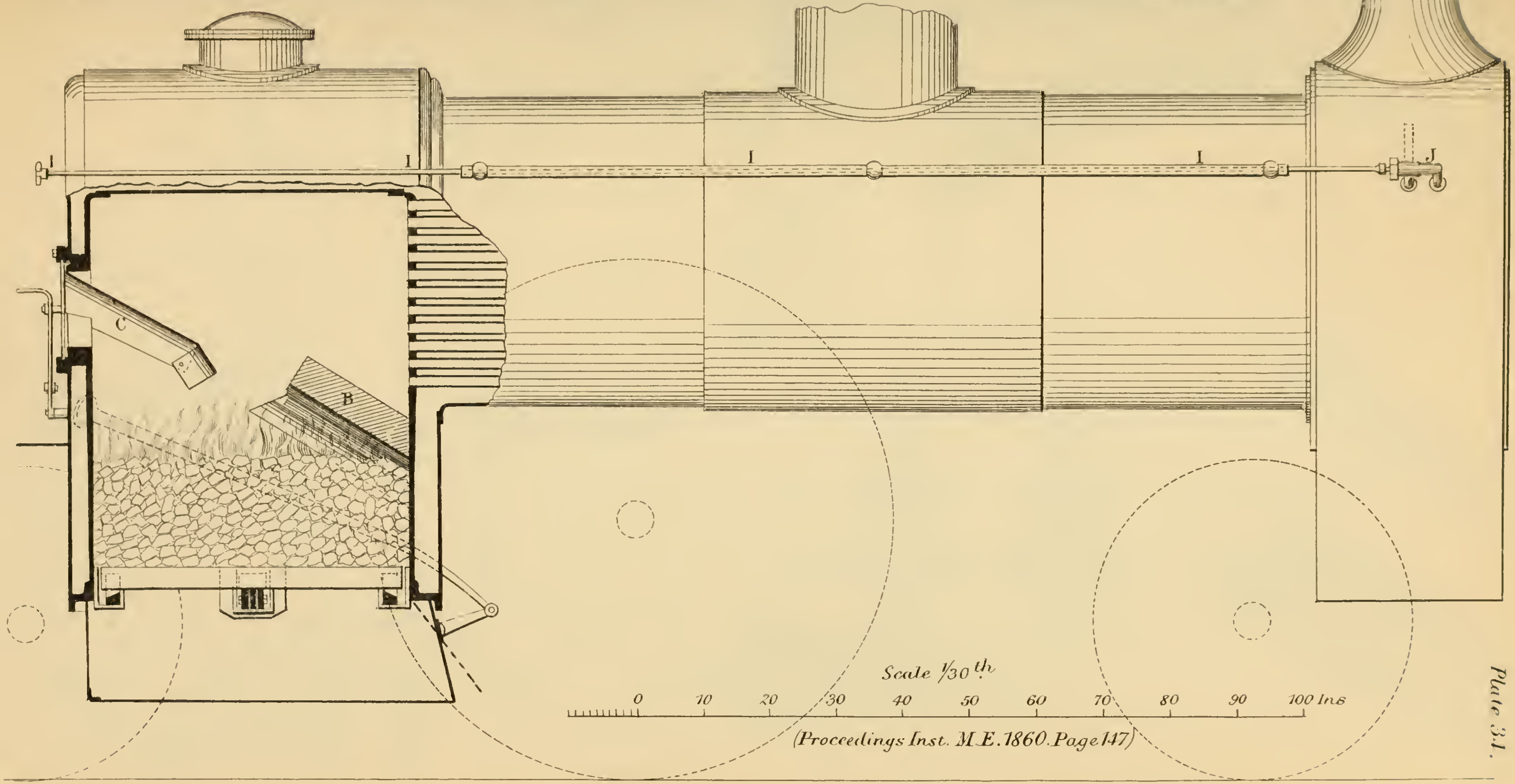
Plate 33

Scale 1/30th 0 10 20 30 40 50 60 70 80 90 100 *Inches*

(Proceedings Inst M E 1860. Page 147)

COAL BURNING IN LOCOMOTIVES.

Fig. 10. *Locomotive with Deflecting Plate, Firebrick Arch, and Steam Jet* — *Present Arrangement.*



(Proceedings Inst. M.E. 1860. Page 147)

Plate 34.

COAL BURNING IN LOCOMOTIVES.

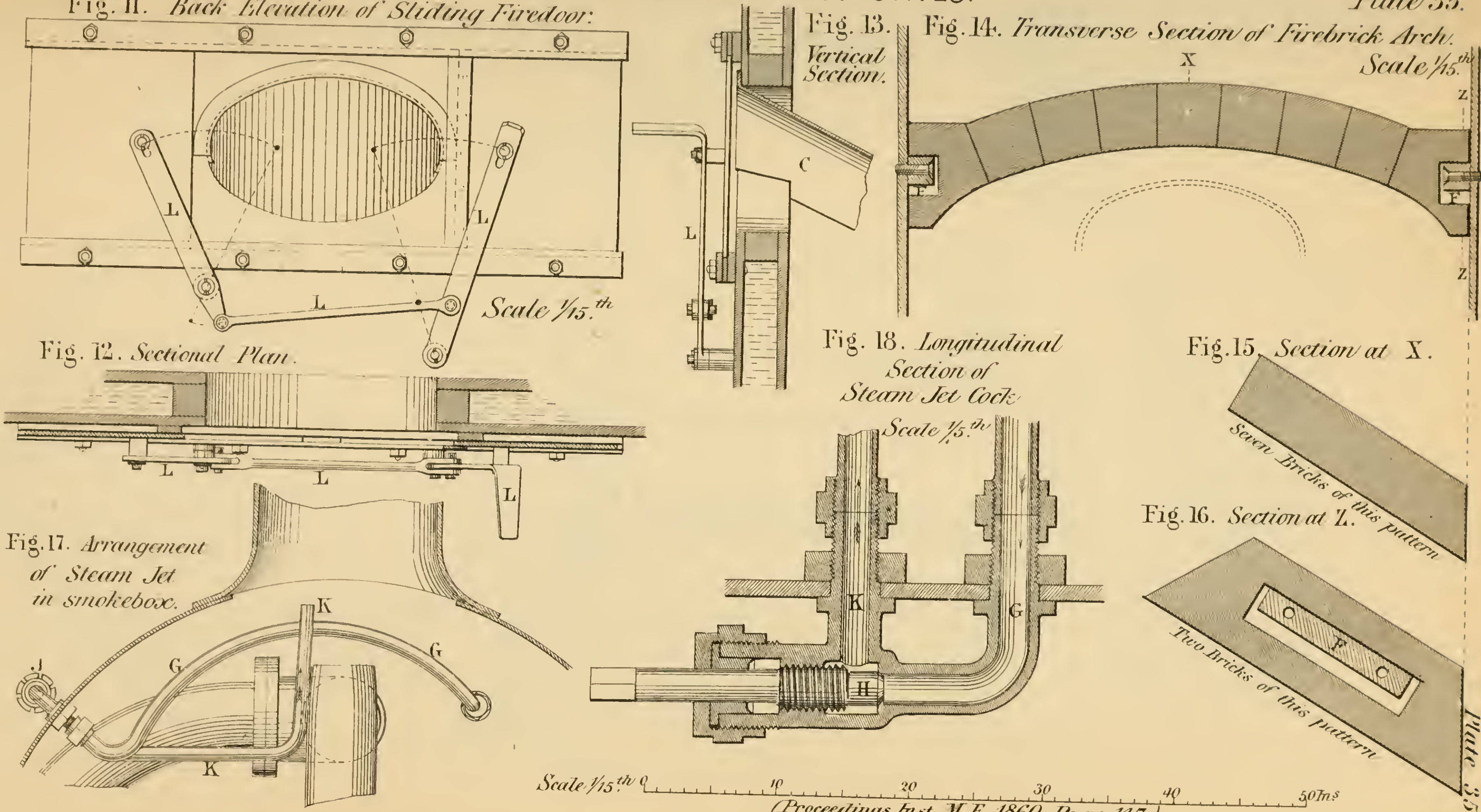


Plate 35.

WATER AXLEBOX.

Fig 2. *Transverse Section at front.*

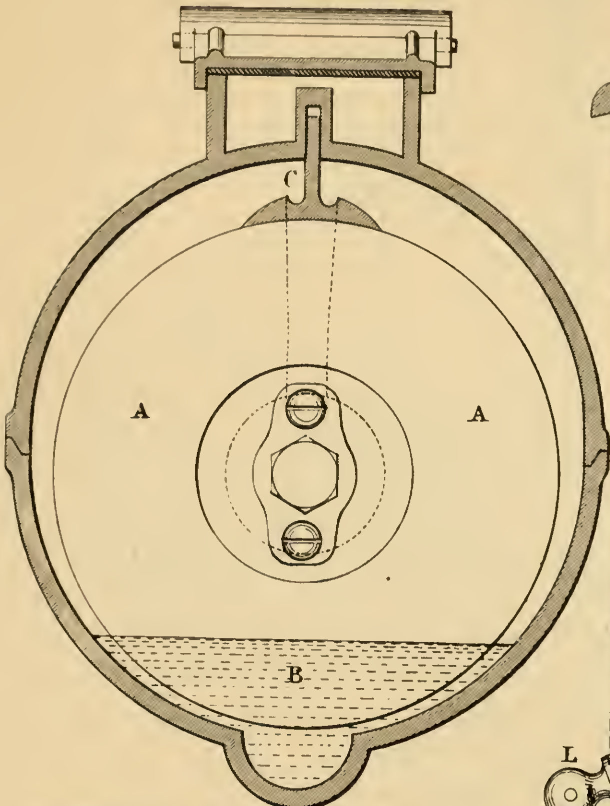


Fig 1. *Longitudinal Section of Aerts' Water Axlebox.*

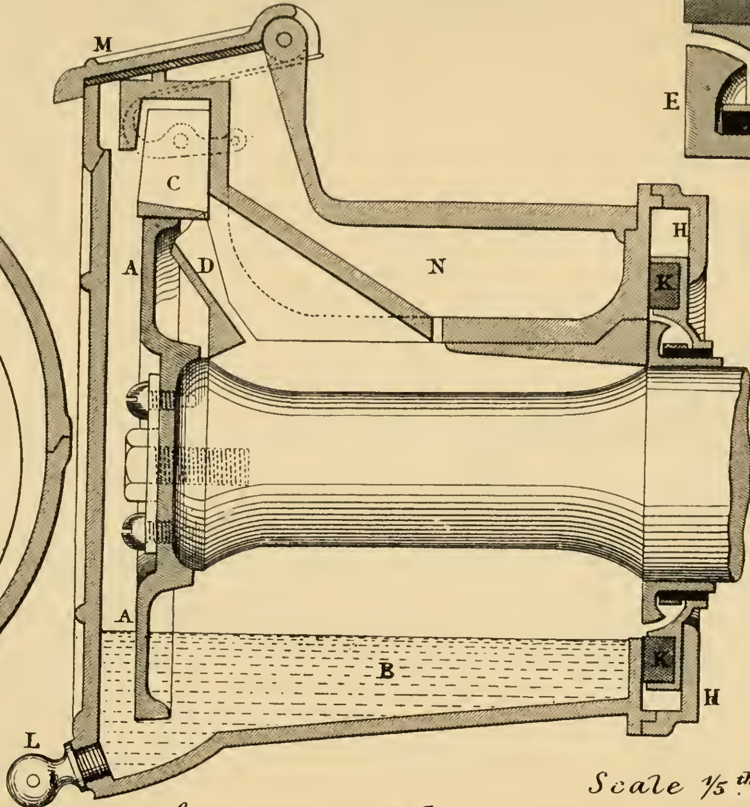


Fig 4. *Scale ½.*

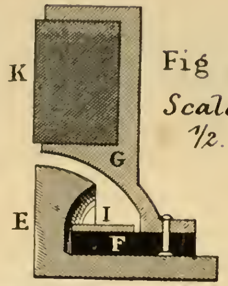
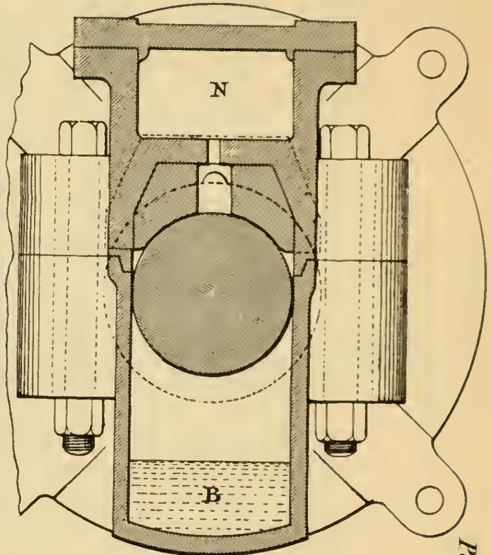


Fig 3. *Transverse Section at centre.*



Scale ⅕th

0 5 10 15 20 Ins.

Plate 36

(Proceedings Inst. M.E. 1860. Page 178.)

WATER AXLEBOX.

Fig 5.
Transverse
Section.

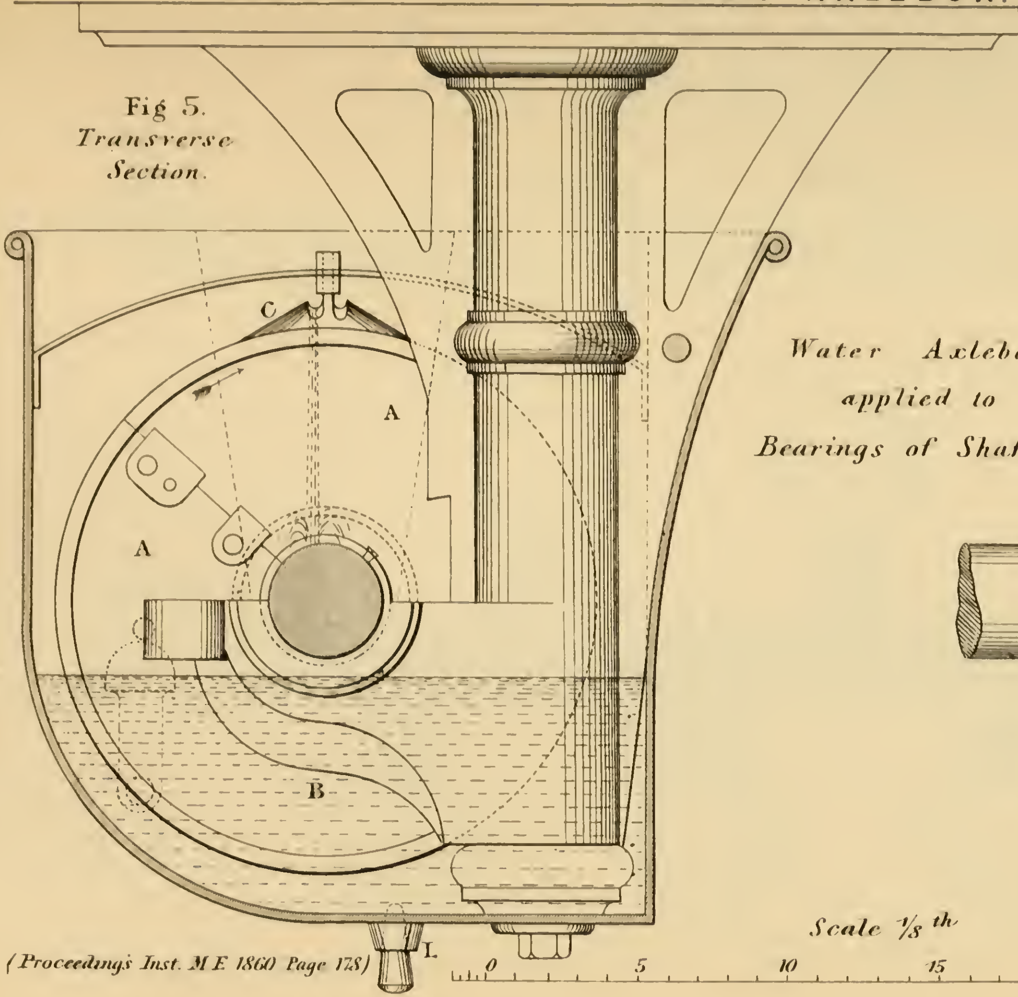
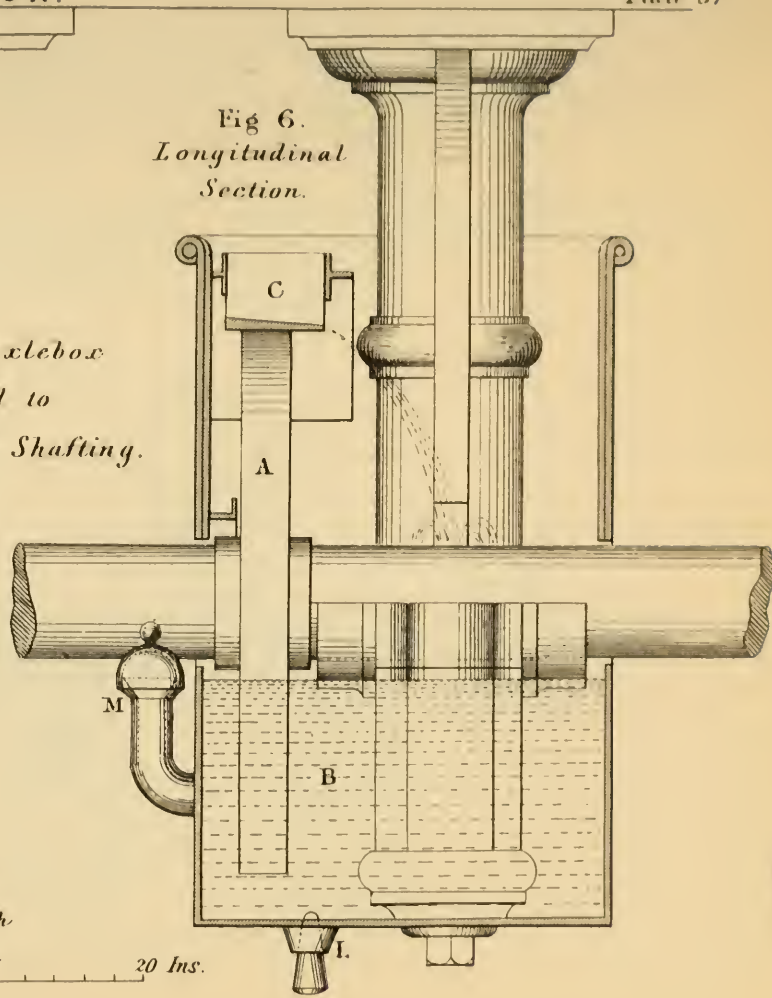


Fig 6.
Longitudinal
Section.



Water Axlebox
applied to
Bearings of Shafting.

Scale 1/8 th
0 5 10 15 20 Ins.

(Proceedings Inst. M E 1860 Page 178)

Plate 37

OPEN COKING.

Fig 1. *Elevation.*

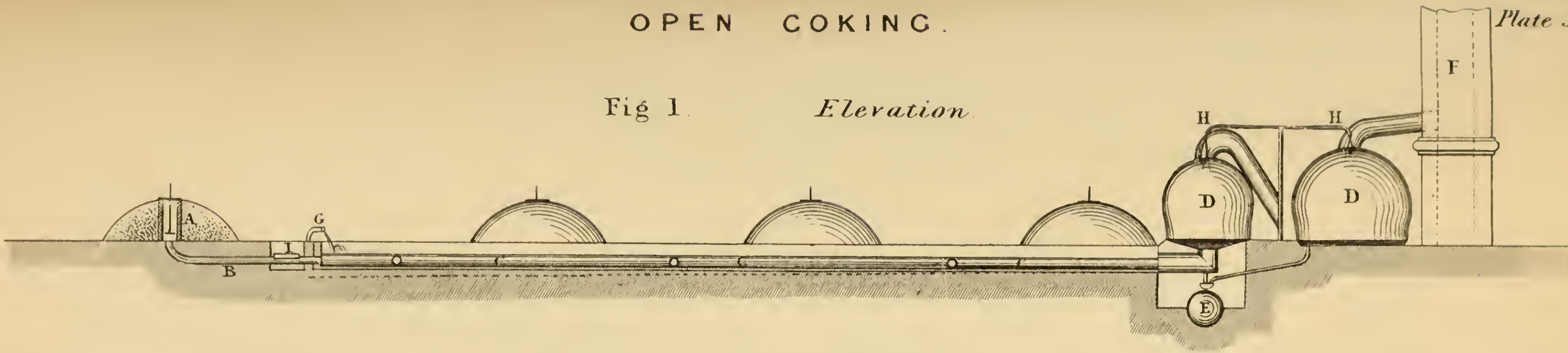
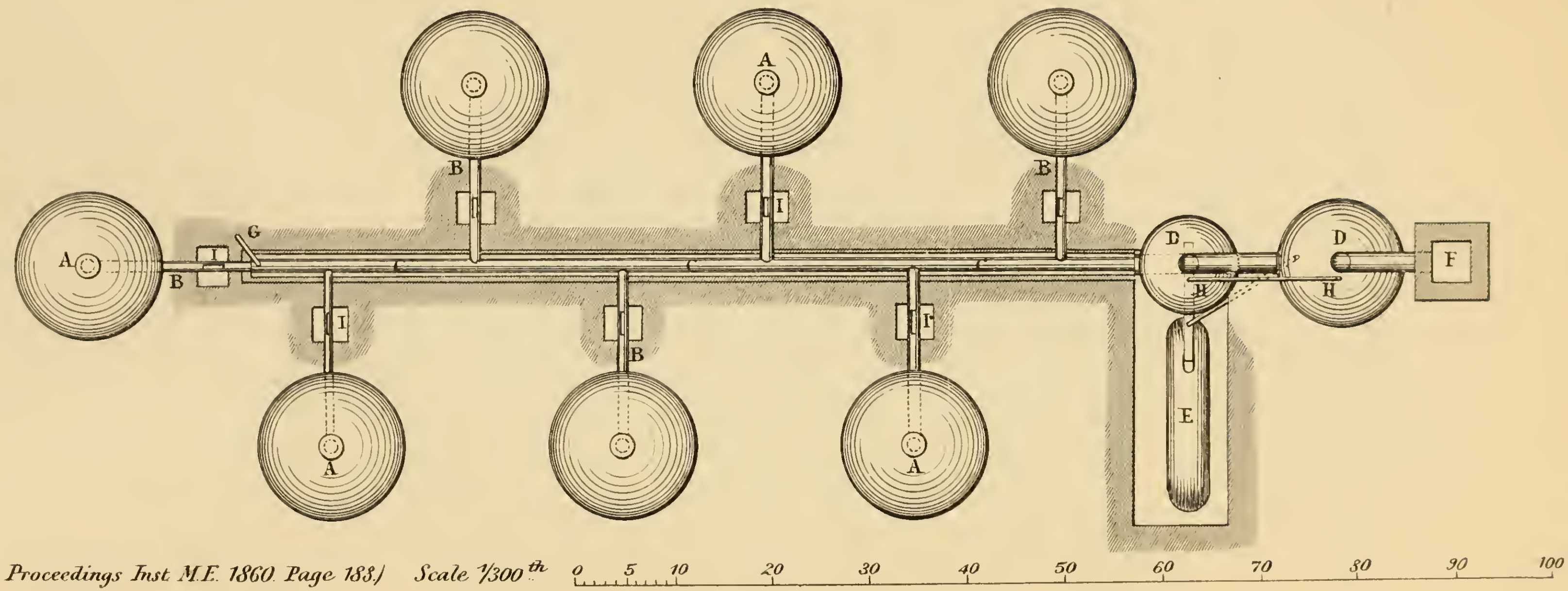


Fig 2. *Plan.*



Proceedings Inst M.E. 1860. Page 188.) Scale 1/300th

Plate 38

DESCRIPTION OF A MACHINE FOR COVERING TELEGRAPH WIRES WITH INDIA-RUBBER.

By Mr. C. WILLIAM SIEMENS, of London.

A submarine telegraph cable is composed of three essential parts :—1st, the conductor, which generally consists of a strand of seven copper wires twisted together, to give it strength and pliability: 2nd, the insulating coating, which consists almost without exception of several coatings of gutta percha put on while hot and in a semifluid state by means of piston and cylinder machines analogous to the presses used for making lead pipes; with intervening coatings of a bituminous compound, called Chatterton's mixture, to establish a more intimate union of the different layers of gutta percha: 3rd, the sheathing, which is added to protect the insulated conductor and to give strength to the cable, and consists generally of a hemp serving and a spiral covering of iron or steel wire.

Respecting the conductor, it is important that it should consist of the best conducting material, in which quality pure copper far surpasses all but some of the precious metals and possibly pure aluminium. If the conductivity of silver is expressed by 100, that of pure precipitated copper may be taken at 90. The conductivity of the copper of commerce varies however between extraordinary limits; and it may be accepted as a rule that all foreign matter contained in it, whether metallic or otherwise, diminishes its conductivity. Thus 2 per cent. of alloy is known to reduce the conductivity of copper from 90 to 13, and even the best selected copper used for telegraph conductors varies in practice as much as 20 per cent. in conducting power. The foreign substance which it is most difficult to remove from the copper is oxygen; and a process to effect this would be of considerable value.

The insulating covering of the conductor is the most delicate and essential part of the telegraph cable. It has to form an effectual barrier against escape of the current throughout the whole length, for

a single flaw in this coating causes the failure of an entire cable. Nor does a flaw show itself always in testing cables however thoroughly previous to their submersion; for experience has proved that flaws are produced gradually by the chemical action of the galvanic current itself in any places where the thickness of insulating coating has been considerably below the average, either owing to an air bubble forced open by the pressure of the water, or owing to an eccentric position of the conductor. The latter defect may be produced either in the covering machine, or afterwards by exposure of the cable to the heat of the sun, or to a strain producing a permanent elongation of the copper; in consequence of such elongation the gutta percha endeavours to return to its original length and causes the copper core by degrees to assume a serpentine position in the covering. Gutta percha was till lately thought almost a perfect non-conductor of electricity; but in dealing with long lines of submarine electric telegraph its conductivity has become well established and is often a source of painful anxiety to the electrical engineer, obliging him to search for other insulating materials. Glass and other vitreous substances, which possess the highest insulating properties, are of course inapplicable; and amongst the resinous insulators there is none that combines insulating quality with tenacity and other desirable mechanical properties in so high a degree as india-rubber. The accompanying table shows the respective non-conducting or insulating power of gutta percha, india-rubber, and Wray's mixture, which last is a compound of india-rubber with shellac and pounded flint; and of the two latter substances combined :—

Specific Non-conducting and Inductive Power of Gutta percha, India-rubber, &c.

	Specific Non-conducting Power.			Specific Inductive Power.		
Temperature Fahrenheit	52°	72°	92°	52°	72°	92°
Gutta percha	3·01	1·20	0·38	1·00	1·00	1·00
India-rubber	50·70	45·10	27·60	0·68	0·62	0·70
Wray's mixture	23·60	26·00	38·40	0·77	0·63	0·96
Combination of India-rubber and Wray's mixture	38·40	49·55	38·40	0·77	0·78	...

The great superiority of india-rubber and its compounds over gutta percha in insulating power is at once apparent, india-rubber itself being 16 times better than gutta percha as a non-conductor at a temperature of 52°, and 70 times better at 92°; and the combination of india-rubber and Wray's mixture is on the average as good a non-conductor as india-rubber, while its inductive power, which causes retardation of the electric current in its passage along the wire, is only three quarters that of gutta percha. To these advantages the greater tenacity of india-rubber and its greater power to resist heat have to be added.

India-rubber has been tried for the purpose of insulating telegraph conductors more than twenty years ago, when it was employed by Jacobi of St. Petersburg for underground telegraphic lines. In 1846 Dr. Werner Siemens employed it for the same purpose, previous to his application of gutta percha. About the same time india-rubber was put to the same use in this country, and it is said remains still in good condition in Portsmouth harbour. There is nothing new therefore in substituting india-rubber and its compounds for gutta percha in insulating submarine or other telegraph conductors: the present paper has special reference to a new method of effecting the covering. The method hitherto adopted consists in cutting the india-rubber into strips, and winding these strips spirally upon the wire to be insulated: a tedious and expensive operation, which has to be repeated several times to afford any security that the water is entirely excluded from the wire. The insulation of the wire depends in fact upon a perfect joint being formed throughout between the strips; for it is evident that where the strips overlap a spiral channel is formed, which if in any one place penetrated will allow the water to spread till it may chance to find a transverse passage into the spiral channel of the next lower coating, and so forth until it reaches the wire. Formerly the layers of india-rubber simply touched one another, and could readily be displaced; but lately a process of soldering the spiral layers has been introduced by Messrs. Silver, which greatly increases the security of the coating, although it does not remove the objections to the spiral channels which must always be formed in lapping. This

process of soldering consists in exposing the covered wire to boiling water for about half an hour, when a most perfect cohesion between adjoining surfaces is produced. The india-rubber so treated adheres to the fingers, or feels sticky; it also loses part of its elasticity and strength. It may therefore be inferred that the heat produces some chemical alteration in the material, changing the gum into an oil. It has been observed that india-rubber so heated has gradually changed bodily into a viscid liquid, where it is in contact with the metal conductor, so as to render it unsafe to be used.

The method of covering which it is proposed to substitute for the above combines the advantages of comparative cheapness and certainty of result with that of rendering the application of heat unnecessary. The operation is based on the well known adhering property of india-rubber, when two fresh-cut surfaces are joined together under considerable pressure. The mechanical problem consisted in the construction of a machine which would draw the india-rubber tight upon the wire, so as completely to exclude air; and would then cut the india-rubber at the proper inclination, and join the fresh-cut edges together at the same instant under a sufficient pressure to make the joint perfect.

The machine finally arranged for this purpose is shown in Figs. 1 to 5, Plates 27, 28, and 29, one quarter full size. Fig. 1, Plate 27, is a side elevation; Fig. 3, Plate 28, an end elevation partly section; and Fig. 5, Plate 29, a plan partly sectional.

The machine consists of two grooved pressing rollers A and B, Figs. 1, 2, and 3, Plates 27 and 28, and of two cutting or shearing rollers CC, all of which are of hardened steel, and are shown enlarged to half full size in the section, Fig. 4, Plate 28. On each side of the groove in the pressing rollers A and B is a small cylindrical portion, as shown enlarged to double full size in Figs. 9 and 10, Plate 30, of a breadth equal or nearly so to the thickness of the intended coating to be applied; but these cylindrical sides must be slightly rounded off towards the groove and sharp on the outer edge, as shown at DD. The cutting rollers C are so placed on each side of the grooved rollers that in turning round their cutting edge crosses the edges of the grooved rollers a little before the centre line of the machine, as shown

double full size in Figs. 7 and 9, Plate 30, at a point where the distance between the edges of the grooved rollers is about equal to half the thickness of one of the strips of india-rubber used. The axis of the cutting rollers is slightly inclined to the axis of the grooved rollers, as shown in the end elevation, Fig. 3, and plan, Fig. 5; so that being pressed against the latter by means of set screws they only touch hard at the shearing point, as seen in Figs. 9 and 10, Plate 30 The wire to be covered and the two strips of india-rubber for covering it are guided into the machine by suitable guides E, Figs. 1 and 5. The two strips in closing upon the wire are drawn tight over it by the inner edges of the grooved rollers A and B; and being caught between the closing cylindrical portions of the grooved rollers are compressed to one fourth their original thickness, the material being forced outwards from the middle; the cutting rollers C then suddenly intersect them, as in Fig. 9, Plate 30, cutting off the superfluous breadth of strips and at the same time preventing further escape of the material towards the sides. As the edges of the grooved rollers continue to close upon one another, the material remaining between them can only escape inwards, by which means the two fresh-cut edges are brought one upon the other under a heavy rolling pressure, from which they glide inwards towards the groove, as in Fig. 10, and in so doing form a complete and permanent joint, Fig. 11. In order to effect several successive coatings, a train of machines is provided, as shown in Fig. 6, Plate 29, so placed that the wire to be coated passes in a straight line through them all, receiving in each successive machine an additional coating, with the longitudinal seams at right angles to those of the previous and succeeding coatings, as seen in Fig. 11, Plate 30, which is effected by the different angular positions in which the machines are placed. The last machine in the train is supplied with strips of cloth or felt covered with india-rubber, which is also capable of being joined by compression of the fresh-cut edges, and is extremely useful in adding firmness and protection to the insulated conductor.

This machine is also applicable, with certain modifications of details, for covering wire with the compound of india-rubber, shellac, and pounded flint, known by the name of Wray's mixture, which

possesses in common with india-rubber very remarkable insulating properties. The machine is also applicable, with great apparent advantage, for the manufacture of india-rubber tubes, and for several other similar purposes. In producing tubes by this process, a spiral or tube of wires is first prepared, which is coated with india-rubber in one or several layers, with or without intermediate layers of canvas previously coated with india-rubber. The spiral wire is then either withdrawn or left to support the tube, which is finally subjected to the vulcanising process.

In order to produce a submarine cable, an outer covering is required for protection and strength. Instead of the ordinary hemp serving and iron sheathing, the author proposes to saturate hemp yarn with a cement consisting of ordinary marine glue mixed with a certain proportion of pitch and shellac, applied to the yarn in a fluid state and under pressure so as to penetrate the fibre completely. Two or more layers of this yarn are put upon the insulated conductor by means of a train of machines, which cause each strand to be drawn tight uniformly, and to pass separately through a heated chamber, so as to soften the cement and unite the yarn in complete layers upon the core, winding alternately right and left. The covering thus produced combines great tensile strength and lightness with the power to exclude the sea water from the core. It thus adds very considerably to the insulating coating, whereby the retarding effect of induction is greatly diminished; and forms a thorough protection to the more tender coating of highly insulating material. The necessity for a metallic sheathing is however not entirely avoided, in order to afford protection against abrasion and against marine animals; and this sheathing is proposed to consist of very thin brass or iron wire wound on in the form of a tight lapping while the cement is still soft, so as to be imbedded completely in it. The cable is then drawn through a hot die, which causes the superfluous cement to cover the wires completely and to preserve them from rusting.

A cable so prepared combines the qualities essential for crossing deep and broad oceans. Its specific gravity will not exceed 1·5, which experience has proved to be the most desirable weight for submersion,

and its tensile strength is such that it will support 15 miles of its own length in sea water, instead of only 3 miles which is the length an ordinary iron-sheathed cable will support. The sheathing of this cable will not be acted upon by sea water, and will retain its full strength therefore in case it should have to be taken up for repairs: it will not be liable to form kinks, which are fraught with danger to the insulation. The chief advantage however is supposed to reside in the insulating coating, which consisting of a succession of perfect tubes of the most highly insulating and tenacious material known, unaltered by heat or solvents and thoroughly protected against external injury, offers the greatest chances for permanent efficiency that could well be realised. For shore ends this cable should receive an additional external covering of strong wires to resist the effects of anchors and violent abrasion; and these wires in their turn should be covered with saturated fibre to render them durable. The experience with long submarine cables has hitherto been anything but satisfactory; but there is in the writer's opinion no reason to prevent their being made very permanent and valuable property, if only the experience now gained is turned to good account.

Mr. Siemens exhibited the machine in action, covering pieces of wire with india-rubber, showing that the joint made by rolling the two fresh-cut edges together under a heavy pressure was so strong that the india-rubber covering would tear at any other part as readily as at the joint. He showed also a number of specimens of the different descriptions of telegraph cable now in use. The process of joining the strips of india-rubber by the machine depended on the well known property of india-rubber, that when two perfectly clean fresh-cut surfaces were pressed together with great force they would unite as completely as two pieces of iron welded together. After many trials for effecting this by machinery, he had now succeeded perfectly with the machine exhibited, in which the two cut edges made by the cutting wheels on each side were instantly pressed together between

the pressing rollers and joined without having been ever exposed to the atmosphere. This was the essential point in the machine, as any exposure of the cut surfaces however momentary interfered with the perfection of the joint. In putting on a series of coats of india-rubber for making telegraph cables, a train of machines was employed through which the wire was passed in a continuous line, the joints in each successive covering being in a line at right angles to those in the previous covering, which gave a greater security against failure at the joint.

This insulating covering had been subjected to severe tests, and proved highly satisfactory and superior to any other mode of insulation. Gutta percha, which had hitherto been the material used for covering telegraph wires, was a good non-conductor; but its resistance to the passage of an electric current was only relative, like that of all other insulating materials, and it would conduct to a certain extent, the conducting power being about 3 trillion times less perfect than that of mercury, which was adopted as the standard of comparison. But india-rubber had much less conducting power than gutta percha, being 16 times better as a non-conductor at a temperature of 52°, and 70 times better at 92°. The insulating power of india-rubber was moreover less affected by difference of temperature than was the case with gutta percha; and in the combination of india-rubber and Wray's mixture, which he had produced, the average insulating power was not less than that of india-rubber, while it was to a less extent affected by change of temperature. Before however a current of electricity could pass along the wire, it had to induce a statical charge in the insulating material throughout the whole length of the wire, as in a Leyden jar; and the delay or retardation thus produced depended on the inductive power of the insulating material, which was independent of its insulating or non-conducting power, but affected by its thickness, the inductive power diminishing as the thickness was increased. A thicker coating of the insulating covering therefore offered less resistance by induction to the passage of an electric current, and allowed of more rapid speaking. In this respect also india-rubber and its compounds had an advantage over gutta percha, its inductive power being about three quarters that of the latter.

In the use of gutta percha as the insulating material, a great amount of care was necessary in the process of coating the wire, and there was great risk of imperfection in the covering. In the submarine telegraph between Rangoon and Singapore the cable was very good for many miles, but a point was then found to exist where the insulation failed from a defect in the original construction of the gutta percha coating; and such defects were liable to arise in the manufacture from various causes. In covering the wire the gutta percha was squeezed forwards in a semifluid state through the die, by means of a piston in a cylinder; and air bubbles were liable to get enclosed within its substance, which were so minute as not to be detected at the time of manufacture, though the cable was tried under a pressure of 600 or 1000 lbs. per square inch; but they were sufficient to impair the insulation at the part where they occurred, and ultimately cause the failure of the cable. Moreover the manufacture was a hot process, as the gutta percha had to be kept soft in coating the wire; and if a slight delay took place in the operation, the gutta percha was too much softened at that part, and the weight of the wire cable itself made the coating thinner on one side than the other, so that the insulation was defective; the electric current afterwards sent through the wire was constantly leaking out more or less at the imperfectly protected parts, and caused a chemical action on the gutta percha, gradually decomposing it at the leak and increasing the amount of leakage. If the finished cable were allowed to lie for only a quarter of an hour exposed to a hot sun, it would be completely spoiled, as the heat would soften the covering and the core would take an eccentric position by sinking through the gutta percha by its weight; and in the event of a strain coming on the cable in laying it, the copper core being non-elastic would remain permanently stretched, while the gutta percha would be constantly endeavouring to regain its original length, forcing the copper by degrees into a serpentine curve. These difficulties had at present caused failures to a greater or less extent in all submarine cables constructed with gutta percha. But in the process now described it was expected that the chances of failure through defects of manufacture would be much diminished, as there was less liability to accidental imperfections in the work, and the durability of the cable was not affected by the temperature to which it was exposed.

Mr. E. A. Cowper observed that the Rangoon and Singapore telegraph cable would support only 3 miles of its own length in water, and its specific gravity was 3 times that of water; but the new india-rubber cable had a specific gravity of only $1\frac{1}{2}$ times that of water, and would consequently support 12 miles of its length in water, if of only the same tensile strength; it appeared really to support 15 miles of its length, which was a most important advantage in point of safety, as submarine cables were liable to have great lengths suspended between the summits of mountains at the bottom of the sea.

The Chairman asked what would be the difference in cost per mile between the new cable and one covered with gutta percha.

Mr. Siemens replied that for equal efficiency, or the same speed of speaking, the new cable would be the cheapest, because a thinner coating of india-rubber would be sufficient to produce an equal insulating effect: but if estimated by weight, a gutta percha cable would be the cheapest on account of the greater cost of india-rubber. The first cost of the cable was however a secondary question, the great object being to obtain a cable that could be depended upon for a number of years. In a gutta percha cable, if the covering were thin at any one place, then each successive current passing along the wire produced an alteration, since the gutta percha conducted at the leak by decomposition of the water contained in its substance; and this action gradually disintegrated its substance and destroyed its insulating power at that part, so that the electric current soon made its escape there.

The Chairman asked how long the new cable would last at work.

Mr. Siemens replied that there was not one of the new cables laid at present, and it required that several hundred miles should have been down for some years in order to show practically its durability in work; but some miles had been made and tested with very satisfactory results, and there was good reason for expecting this construction of cable would prove far more durable than those hitherto laid.

The Chairman moved a vote of thanks to Mr. Siemens for his paper, which was passed.

The following paper was then read:—

ON THE BURNING OF COAL INSTEAD OF COKE IN LOCOMOTIVE ENGINES.

By Mr. CHARLES MARKHAM, of Derby.

During the last six or seven years the question of burning Coal instead of Coke in Locomotive Engines has been a constant subject of enquiry and investigation: nevertheless great diversity of opinion still prevails in the minds of practical men.

The economical substitution of coal for coke must be considered with reference to the locality where it is employed. In some parts of the country hard steam coal is considerably cheaper than coke; whilst in the Durham district coke can be purchased at a lower price per ton than the best hard steam coal, which does not exist in that locality. The Durham cokes, such for instance as Pease's West and Brancepeth, are by general consent acknowledged to be the best locomotive cokes in the country, having been found superior to the Welsh cokes in density and durability. The North Country cokes were formerly manufactured from the purest small coals; but of late years the refuse small coal, which contains a considerable proportion of earthy matter and which was formerly thrown away and ultimately took fire by spontaneous combustion, has been manufactured into coke. The earthy matter is separated from the coal by a washing process: the earthy particles sink to the bottom, whilst the coal which is of less specific gravity remains at the surface. The price of the North or Durham cokes varies at the coke ovens from 8*s.* to 9*s.* per ton: the present price paid by the Midland Railway at Normanton is 15*s.* per ton, the Company finding their own wagons. The Midland Railway runs through very extensive coalfields in the counties of Yorkshire, Derbyshire, Nottinghamshire, and Leicestershire, and also through a small coalfield in the neighbourhood of Bristol. Excellent steam coal can be obtained from these various districts at prices which

give a general average of rather less than 7*s.* 6*d.* per ton. It is therefore evident that the substitution of coal for coke on the Midland Railway is a subject of great importance. When it is considered that upwards of 2 tons of coal can be purchased for the same price as 1 ton of coke, and that the total cost of coke consumed by the Midland engines has been in former years upwards of £94,000 per annum, it is evident that a very considerable saving would be effected by the successful substitution of coal for coke.

Coal was burnt in some of the early locomotives, which were constructed with a return flue; and many of these engines are still working on the Stockton and Darlington Railway. They consume the smoke with tolerable success whilst running, in consequence of the large area of the flue or combustion chamber, which most materially tends to facilitate combustion; but they are deficient in heating surface. Coal was also used in the early multitubular locomotive boilers; but it was discontinued and coke substituted shortly after the opening of the Liverpool and Manchester Railway; and coke has been the fuel generally consumed in the ordinary locomotives of this country until within the last six or seven years. In 1853, on account of the great development of the railway system throughout the country, the Midland and most of the great railways were unable to obtain a sufficient supply of coke for conveying their traffic. The Midland Railway was consequently compelled to burn coal instead of coke. But the use of coal for this purpose was attended with great inconvenience and difficulty. The smoke at that period was an intolerable nuisance; and the difficulties of conducting the business of the railway were greatly augmented in consequence of the engine drivers not being able to maintain a proper pressure of steam. The smokeboxes also were constantly getting red-hot from the decrepitation of the coal; the small particles of coal were drawn into the smokebox, and taking fire there warped the doors, whereby a considerable quantity of air was admitted, which prevented a sufficient draught being produced by the chimney.

About 17 or 18 years ago Mr. Samuel Hall of Nottingham obtained permission to attempt the combustion of coal in some of the Midland locomotives. The plan adopted for the purpose was that of cutting

airholes into the firebox immediately above the surface of the fire, and connecting some of the tubes at the chimney end with pipes that were carried through the smokebox and opened out into a trumpet or funnel mouth in front of the engine: the object being to collect the air and force it through the tubes into the centre of the firebox whilst the engine was running. Brick arches were also applied in the firebox. This plan however was ultimately abandoned, as the smokeboxes were constantly getting red-hot, and the engines were unable to perform the work in a satisfactory manner. About the same time Mr. Chanter constructed a multitubular boiler to burn coal, having three vertical brick partitions, supported by transverse iron tubes containing water, extending across the firebox from side to side and reaching down to the top of the fuel; the smoke and air passed through the space between these partitions before entering the tubes. The engine was tried several times on the Birmingham and Derby Railway, and the smoke was almost wholly consumed: but it did not answer on account of the top of the firebox being unfortunately about 9 inches above the barrel of the boiler, which was filled with tubes; the steam room was therefore insufficient to prevent priming, for whenever the regulator was opened the cylinders were partially filled with water, and the engine was consequently unable to perform the necessary work. It remained in a siding at Derby for several years, and was ultimately sold and sent into Wales.

These early attempts at smoke burning, like new inventions generally, were too complicated in their details, which by subsequent improvements gradually became simplified. The North Country coke was manufactured and introduced about this period; and no further attempts were made to substitute coal for coke on the Midland Railway until 1852, when a small proportion of coal was mixed with the coke with satisfactory results. Since 1856 a great number of experiments have been made to burn coal upon the various railways, and especially with a view to its employment in locomotives of the ordinary construction. Almost every railway has adopted some special and peculiar method for this purpose; and each method is considered by its advocates superior to any other.

For the complete combustion of coal it must be premised that it is essential the gases given off by its distillation should be heated to a very high temperature; otherwise they will not be entirely converted into carbonic acid gas and water—the ultimate products resulting from the complete decomposition of the carburets of hydrogen. Whenever the gases come in contact with the metal surfaces of the firebox or tubes, which are surrounded by water, they are immediately cooled down by the rapid conducting power of the metal, and their complete combustion is thereby rendered impossible, because this cannot take place except at a red heat or a very high temperature. Another condition requisite for the complete combustion of coal or coke is the presence of an excess of atmospheric air to ensure the complete conversion of the carbon into carbonic acid gas. Unless these two essential conditions are complied with, the burning of coal in locomotives can never be successfully accomplished. When locomotives are in motion the exhaust steam is expelled through the blast pipe and causes a partial vacuum to be formed in the chimney, sufficient to create a considerable draught upon the fire; and so long as the engine is working and in motion the smoke is consumed, provided the gases are sufficiently heated and mixed with an excess of atmospheric air. But when the engine is brought to a stand, the distillation of the gases continuing and the blast ceasing, a considerable amount of smoke would inevitably escape into the chimney if the draught were not maintained. This is effected by the application of a jet of steam, which is allowed to escape into the chimney, causing an artificial draught sufficient to draw the necessary supply of air over the surface of the fire and consume the smoke. It is also necessary that ashpan dampers should be fitted air-tight to the firebox, so as to regulate the admission of air through the firebars, and exclude it as far as possible when the engines are standing, in order to prevent the combustion of the coal. The mode of accomplishing the combustion of the coal is different in the various plans now in operation; but the efficiency of all coal-burning apparatus depends upon the fulfilment of the general conditions that have been described.

It is therefore evident that the ordinary method of filling up the fireboxes of locomotives with coal and shutting close the firedoors

must occasion the production of smoke, which passes off unconsumed. The distillation of the coal gases commences at a comparatively low temperature, whilst their ultimate combustion requires a high heat and an excess of air. The gases begin to be given off immediately fresh coal is added to the fire, and it is therefore necessary that fresh coal should not be added to the fire when the engines are standing at stations or approaching them. Printed orders have consequently been issued to the enginemen and firemen employed on the Midland Railway to the effect that coal is to be thrown into the firebox only when the engines are leaving stations; and the next stopping place is to be approached with a bright fire, the ashpan damper closed, the firedoor wide open, and the steam jet applied and continued so long as the regulator is closed, if the least smoke is observed issuing from the chimney.

The first series of experiments that were undertaken on the Midland Railway were made with engines in which air tubes of 2 inches diameter were inserted into the firebox below the firedoor, as well as at the sides immediately above the surface of the fire, on the same plan that had previously been adopted by Mr. Hall.

The next experiments, from which tolerably satisfactory results were obtained, were made with an engine having air tubes inserted into the front of the firebox, immediately under the tubes, as shown at A in Figs. 1 and 2, Plate 31; a brick arch B being added above the air tubes, and a deflecting plate C fastened on the firedoor, projecting downwards into the firebox. A good deal of air was forced as well as drawn into the firebox through these air tubes when the engine was in motion and running forwards, which meeting the gases in the centre of the box caused a considerable portion of them to be properly burnt. It was however observed that, in the case of goods engines, when they were burning from 50 to 60 lbs. of coal per mile, a large quantity of unconsumed smoke was still given off, showing that a sufficient quantity of air was not admitted into the firebox. For whenever a large quantity of steam was required in a short period, some of the air tubes had to be partially closed in order to obtain the necessary pressure of steam in the boiler, which occasioned a deficiency

in the supply of air for burning the smoke. In this case, as in all coal-burning engines, whenever a fresh supply of coal was added to the fire a considerable quantity of smoke was given off. The cause in every instance is the same: the upper part of the fire being cooled down by the fresh supply of coal, the heat immediately over the surface of the fire is reduced below the temperature at which the gases can be burnt. Every attempt that was made to increase the opening through the firedoor and to deflect the air down upon the surface of the fire was attended with a striking improvement in the more perfect consumption of the smoke. The deflecting plates attached to the firedoor were therefore gradually lengthened, and at last made to project 9 inches into the firebox.

Another plan for deflecting the air on to the surface of the fire was suggested by Mr. Burn, formerly of the Midland Railway, by means of a plate C, Fig. 3, Plate 31, hinged inside the firebox, and adjusted in different positions by the rod D with notches cut in it. The first experiment made with an engine fitted on this plan appeared satisfactory: but further experience showed that when the plate was lowered the air was deflected only a short distance into the firebox, so that the smoke was imperfectly consumed, and the driver could not keep up the necessary supply of steam, while the plate became rapidly warped by the heat. These difficulties ultimately led to the abandonment of this plan.

An experiment was then tried to form a combustion chamber in the firebox, as shown in Figs. 5 and 6, Plate 32, by means of eleven firebrick bars B, 4 feet long by 10 inches deep and 2½ inches thick, placed close together and fixed in the firebox. The firebrick surface thus exposed to the fire amounted to about 70 square feet, so that when the bricks became red-hot the smoke was tolerably well consumed. The firebrick bars however placed in this position did not answer satisfactorily, the bottom ends being rapidly destroyed by the action of the fire and the alternate expansion and contraction. Arches formed of ordinary firebricks 9 inches by 4½ inches were again tried with better results, and lasted several months; but they were liable to destruction in consequence of large lumps of coal falling on them in firing and breaking or displacing the bricks, and also in consequence

of want of care and attention on the part of the firemen when cleaning the fire or pulling it out of the engine. These arches were sprung transversely from side to side of the firebox and close to the tube plate, and were supported by means of solid wrought iron bars about 2 feet long by 2¼ inches square, bolted to the sides of the firebox by two or three tapped bolts, the brick arches being sprung from the top of these supporting bars, as shown in Figs. 1 and 2, Plate 31. It was thought that the conducting power of the metal would be sufficient to keep the iron supports cool; but experience soon showed that the oxidation of the iron was considerable and that a few months' work was sufficient to reduce the bars considerably. This difficulty however was not considered of much importance, as the substitution of new iron bars in place of those destroyed could be effected in a few hours and at a small cost.

It was observed that every addition made to the length of the deflecting plate attached to the firedoor was attended with marked improvement in the combustion of the smoke, the plate causing the air to be deflected on to the surface of the fire, and the combustion of the coal within the range of the deflector taking place at the surface instead of the centre of the fire. These facts strongly impressed the writer with the necessity of endeavouring to burn the coal from the top of the fire downwards, instead of from the bottom upwards as in the ordinary method. It was impossible to prolong the deflecting plate further into the firebox if attached to the firedoor; the writer therefore determined to try a semi-cylindrical plate 3 feet long, flanged and placed in the firebox independent of the firedoor, in the manner shown in Figs. 7 and 8, Plate 33, and enlarged in Fig. 13, Plate 35. The extraordinary results that were accomplished by this simple plan surpassed the most sanguine expectations. The air drawn into the firebox was deflected on to the surface of the fire, and the coal took fire at the surface and burnt downwards, so that steam was raised with greater rapidity and the smoke consumed more completely than in any of the previous experiments. Several engines were at once fitted up with similar deflecting plates, and with such satisfactory results that it was soon determined to apply the same plan to all the engines on

the Midland Railway; and there are 240 of the engines in steam daily with these long deflecting plates. It was found by experiment that the end of the deflecting plate should be bent down at about the inclination shown in Fig. 7, so as to deflect the air on to the surface of the fire at E. The draught created by the blast pipe is not altogether continuous, as each beat of the engine causes the air to be drawn into the firebox with a varying velocity; the effect of which is to create a flapping motion of the air and gases in the firebox, whereby their mixture and final combustion is materially facilitated. Another striking and satisfactory result obtained by this plan is that the smoke is more perfectly consumed when the firebox contains a full body of fire; for the heat from the full body of fire causes the gases to be raised to a high temperature, and as they rise to the surface of the fire they are met by the current of air that is deflected down upon the surface of the fire; in this way the combustion of the coal is rendered almost complete. In all previous experiments it was found desirable to run the engine with a very thin fire, so as to permit a considerable quantity of air to pass up through the firebars; but this method was uncertain in practice and the results were never satisfactory.

As soon as it was determined that the ordinary engines should be fitted up with the long deflecting plates C, Figs. 7 and 8, Plate 33, the writer turned his attention to the practicability of applying the same plan to engines with a midfeather or transverse water partition in the firebox, as shown in Fig. 9, Plate 33. The difficulty however of supplying the front part of the firebox with fuel whilst the deflecting plate was a fixture in the firedoor appeared at first insurmountable, unless the plate were lifted out of the firebox every time of firing; but this was overcome by making the plate to be tilted up by a lever D fixed on the back end, as shown by the dotted lines. It was afterwards found that the lever could be entirely dispensed with by the fireman placing the shovel in the firedoor, tilting the plate up and fixing it temporarily in its raised position by a piece of coal or wood placed between the flange of the plate and the back of the firebox, the prop being removed after throwing in the last shovelful of coal upon the fire. Fortunately the Midland Railway has only 26 engines with midfeathers out of a stock of 459. All the midfeather

engines were at once fitted up with deflecting plates, and they have been found to consume the smoke in a very satisfactory manner. The great drawback to burning coal in engines of this class arises from the difficulty of cleaning the front part of the firebox and removing the clinker that forms on the firebars. This difficulty is found to be much increased in cases where the coal consumed contains a large proportion of clinker; and in such cases it is desirable to remove the midfeather, more especially as experience has long established the fact that a midfeather is not attended with any practical advantage or economy.

It having been observed that the firedoors were kept constantly wide open in the regular working of the engines, it appeared desirable to increase still further the area of firedoor; and consequently the new engines that have since been built and are now in course of construction on the Midland Railway have the firedoors enlarged to 18 inches wide by 11 inches high, as shown in Fig. 11, Plate 35, giving an area of 1·1 square foot, which is 20 per cent. greater than that of the ordinary firedoor, and the alteration has been attended with most satisfactory results. The ordinary mode of fixing the firedoors on hinges being found very inconvenient, on account of the doors projecting on to the foot plate, a trial was made of sliding doors, fitted as shown in Figs. 11, 12, and 13, and arranged to move in pairs by means of the levers L. This plan answers well; and another advantage resulting from it is that, whenever the doors have to be partly closed, the air still enters at the centre and is deflected down into the middle of the firebox, instead of passing in at one side of the firedoor as in the old plan. A large extent of heating surface is essential for the successful working of coal-burning engines, and especially for engines fitted up with the deflecting plates; for in consequence of the firedoor being generally kept wide open, it is impossible to obtain the same degree of vacuum in the smokebox as when the door is shut. When the door is open, the air enters freely into the firebox; but when a larger quantity of steam is required than the boiler can properly supply, it is necessary to close the door partially, in order to create a greater draught upon the fire.

On further experience, notwithstanding that the deflecting plates accomplished the combustion of the coal efficiently, the writer considered that a further improvement would be effected if a firebrick arch could be applied in the firebox in a substantial manner. It was evident that the gases given off from the coal close to the tube plate and immediately below the tubes were liable to be drawn into the tubes before being sufficiently heated and mixed with air for their combustion; moreover the small particles of coal that decrepitated and were drawn through into the smokebox were liable to take fire there. By the application of a brick arch close to the tube plate the unconsumed gases and small particles of coal would be compelled to pass over a more extended surface in the firebox before entering the tubes, and would be heated by the bricks and their combustion thus rendered more perfect. Brick arches 20 inches long were consequently fixed in the position shown at B in Fig. 10, Plate 34, so as to prevent the liability of the bricks being broken or displaced by the fire tools or by careless firing. The firebrick arch as designed and now applied by the writer is shown enlarged and in detail in Figs. 14, 15, and 16, Plate 35, and is formed of nine firebricks, seven of the pattern shown in Fig. 15, 20 inches long by 5 inches thick, and two side bricks of the pattern shown in Fig, 16, having recesses to admit of their being supported from the sides of the firebox by the square bars F or pieces of angle iron, which are thus preserved from injury by being completely covered by the firebrick, so that the oxidation of the iron which took place in the first experiments made in supporting brick arches is prevented.

Simplicity of construction is in all cases of such great importance that it would not be advisable to adopt the brick arch in combination with the deflecting plate, if its application were attended with much trouble or expense; especially as experience has shown that the coal smoke is almost entirely consumed by the simple application of the deflecting plate with a proper adjustment of the opening of the firedoor. The brick arch however, as now constructed and shown in Figs. 10 and 14, Plates 34 and 35, can be maintained without much trouble or expense, and it undoubtedly contributes to the more perfect combustion of the smoke and small particles of coal. It is

therefore desirable that it should be generally adopted in combination with the deflecting plate, particularly when the coal to be burnt contains much volatile matter : and the arrangement of deflecting plate and brick arch shown in Fig 10, Plate 34, is that now adopted on the Midland Railway.

Coal however cannot be perfectly consumed in locomotives without some extra care and trouble on the part of the enginemen; it is therefore important to supply them with every facility for enabling them to comply with the necessary condition of consuming the smoke under all circumstances, and for this purpose the steam jet is indispensable. The mode in which it has been applied by the writer is shown at J in Figs. 10 and 17, Plates 34 and 35, and the steam jet cock is shown enlarged in Fig. 18, Plate 35. The steam in the pipe G from the boiler is constantly pressing against the plug H, which fits up against a shoulder forming the joint; when the rod I is turned, the plug is drawn back, and the steam escapes into the chimney through the pipe K. The rod I passes through the handrail along the side of the boiler and is worked from the foot plate, as shown in Fig. 10; and there is so little trouble in applying the steam jet on this plan that it is rare to find drivers approaching stations omit to turn it on on acccount of the extra trouble.

Since the use of coal in locomotives has become universal on the Midland Railway, it has been found necessary to diminish the air passages between the firebars, on account of the quantity of small particles of coal that fall through the bars into the ashpan; 23 bars have therefore been adopted in place of 21. The firegrate area of the ordinary goods engines of modern construction is 14 square feet, the air passages amounting to 5 square feet and the firebars to 9 square feet; the air passages consequently are only 36 per cent. of the total grate area. It may be doubted whether this porportion is properly adjusted; and it is desirable that attention should be directed to the investigation of this subject. Reducing the area of firebars and increasing that of the air passages may probably result in increasing the capacity of the boilers to generate a larger quantity of steam in a shorter time without increasing the size of the firebox. Where coke is used in locomotives the combustion takes place from the bottom of the firebox, the

admission of air under the firebars being regulated by the ashpan damper, which in the Midland engines was formerly kept almost always wide open when burning coke, giving an area of about 3 square feet of opening for the entrance of air below the firebars. But since the substitution of coal, the area of opening of the ashpan damper in nine passenger and seven goods engines, in daily work and taken indiscriminately, has been found to be $1\frac{1}{2}$ square foot in the passenger engines and 1 square foot in the goods engines. All coke contains a certain proportion of slag and earthy matter which very soon covers the bars with an incrustation of ashes and dirt; consequently unless the bars are wide enough apart for some of the ashes and slag to shake through into the ashpan, the boiler will not generate the necessary supply of steam. Some years ago the writer made a series of experiments with the Tapton and Staveley cokes, the former having been used for many years in some of the small engines that were employed in working the light traffic of the railway; and it was always found that at the beginning of the day's work the engines raised steam with great rapidity, but after running 20 or 30 miles the firebars became covered over with a thick incrustation of ashes and slag, whereby the air passages between the bars were stopped up. Hence unless the firebars were continually cleaned and the slag removed, the engines were unable to perform their required duty. These difficulties ultimately led to the complete abandonment of the Derbyshire cokes and the entire substitution of the North coke, which contains a much smaller proportion of earthy matter; the best coking coals of the Durham district being in fact nearly altogether free from clinker. In burning coal, the incrustation of clinker on the firebars is easily broken up and removed through the firedoor in large pieces, the enginemen generally taking care to run the fire low for this purpose when approaching terminal stations where they are detained to turn the engine ready for the return journey.

The advantages attending the plan of burning coal in locomotive engines, as above described and now adopted on the Midland Railway, are that the ordinary locomotives can be converted into excellent coal-burning engines at a trifling cost; and that when altered they perform the work and consume the smoke with greater efficiency than

is obtained by any other system yet adopted, notwithstanding that the most complicated boilers have been constructed at great cost for the special object of burning coal.

The following tables exhibit a series of experiments that have been made on the Midland Railway from time to time to ascertain the relative value of different descriptions of coal and coke in locomotive engines working with the regular trains. Table I is a general summary of the results obtained from the whole of the experiments, classified according to the district of the fuel tried. In Table II (appended) are shown the average results with each description of coal and coke in the several districts; and Table III (appended) gives the particulars of each experiment in detail. In every experiment the

TABLE I.

General Summary of Experiments.
Evaporative Power of different descriptions of Coal and Coke in Locomotive Engines.

Nos. of Experiments.	Description of Fuel, and District.	Distance run.	Fuel consumed.		Water evaporated.	
			Total.	Per mile.	Total.	Per lb. of fuel.
Nos.	COAL.	Miles.	lbs.	lbs.	lbs.	lbs.
1–56	Derbyshire	7415	281,985	38·0	1,875,829	6·7
57–61	Durham	681	28,672	42·1	217,927	7·6
62–67	South Yorkshire	660	16,464	24·9	126,206	7·7
68–73	Leicestershire	692	19,894	28·7	127,079	6·4
74–80	South Staffordshire	868	30,226	34·8	192,981	6·4
81–85	Forest of Dean	640	32,816	51·3	228,040	6·9
86–89	Bristol	512	26,432	51·6	198,800	7·5
90–99	South Wales	1409	38,162	27·1	310,631	8·1
	COKE.					
100–109	Derbyshire	1324	51,394	38·8	362,057	7·0
110–129	Durham	2640	127,927	48·5	1,015,199	7·9
	STATIONARY ENGINE.					
130–141	Derbyshire Coal		62,440	...	420,275	6·7
142–153	Durham Coke		56,952	...	422,980	7·4
154–159	Mixed Coal and Coke		27,160	...	190,187	7·0

fuel consumed includes getting up steam. The following are the equivalent quantities of coal and coke from the several districts required to evaporate the same quantity of water in locomotives, taking the South Wales coal as the standard at 100, having the highest evaporative duty: and also the calculated relative values of the coals per ton, in reference to their evaporative duty alone, taking the South Staffordshire coal as the standard at 7*s.* per ton:—

District.	Water evaporated per lb. of fuel.	Equivalent Quantities of Fuel required.	Relative Evaporative Value per ton.
COAL.	lbs.	Equivalents.	Shillings.
South Wales	8·1	100	8·86
South Yorkshire	7·7	105	8·42
Durham	7·6	107	8·31
Bristol	7·5	108	8·20
Forest of Dean	6·9	117	7·55
Derbyshire	6·7	121	7·33
Leicestershire	6·4	127	7·00
South Staffordshire	6·4	127	7·00
COKE.			
Durham	7·9	103	...
Derbyshire	7·0	116	...

The Derbyshire hard steam coals do not contain a very large proportion of volatile matter, and are much inferior to the Welsh and the North or Durham coals in their evaporative power, as seen in the above Table I. The latter description of coal contains a considerable proportion of gases; consequently its use in locomotives renders the application of the brick arch desirable in order to secure proper consumption of the smoke. The Derbyshire hard steam coals are known in the district as the Top Hard and Bottom Hard coals. The Top Hard coal is much superior to the Bottom Hard in every essential quality: it gives off less smoke, is much more durable, evaporates a larger quantity of water, and contains considerably less ashes and clinker; the latter quality being of the greatest importance in its practical application in locomotives. This coal occupies a considerable district north east of the main line of the Midland Railway from Derby to Leeds. The

Staveley hard coal has been for several years extensively consumed in the locomotives on the Midland Railway, having been found admirably adapted for the purpose, and is still very extensively used. There is however every reason to believe that inferior coals will ultimately be used in locomotives with economy and efficiency.

The economy obtained on the Midland Railway by burning coal instead of coke in the locomotives has been very considerable. The average evaporative duty of the Derbyshire hard coals being about 6·7 lbs. of water per lb. of coal, and that of Durham coke being about 7·9 lbs. per lb. of coke, as seen in the above Table I, it follows that about 18 per cent. more coal will be required to evaporate the same quantity of water as coke. It has not yet been ascertained by experiment what percentage of coal has to be added for the loss occasioned by the steam jet; for whenever the jet is turned on, all the steam escaping through into the chimney as well as that from the safety valves is so much loss of power from the boiler. The mileage performed by the engines of the Midland Railway for the year ending 30th June, 1860 has been 9,101,460 miles. The fuel consumed during the same period has been

Coal	116,619 tons . .	or .	75·7 per cent.
Coke	37,413 tons . .	or . .	24·3 per cent.
Total . . .	154,032 tons.		100

But during the past half year the proportion of coal has increased and the consumption has been

Coal	67,559 tons . .	or . .	82 per cent.
Coke	14,737 tons . .	or . .	18 per cent.
Total . . .	82,296 tons.		100

Coal would have been more extensively consumed on the Midland Railway during the past year, had not engagements been made for receiving large quantities of coke. The sum expended for the fuel consumed in the locomotives for the year ending June 1860 was £75,162, giving an average cost of 1·98*d.* per mile run. The average cost of fuel for the two years ending December 1856 was

£93,265 per annum, at an average cost of 3·05*d.* per mile. The saving of 1·07*d.* per mile run, multiplied by 9,101,460 miles, the mileage for the past year, shows a total saving of £40,577 as compared with 1855 and 1856.

The total cost per engine of the alterations necessary to convert the ordinary locomotives into coal-burning engines according to the plan that has been described is as follows :—

	£	*s.*	*d.*
Steam Jet and connexions complete	2	8	8
Sliding Firedoors with levers, guides, &c.	2	2	6
Deflecting Plate	0	6	6
Brick Arch and supporting bars	0	19	1
Total	£5	16	9

The annual cost of maintenance has not yet been accurately ascertained; but it is believed that under ordinary circumstances it will not exceed £2 10*s.* per engine if deflecting plates alone are used, or £3 if brick arches are applied in addition to the deflecting plates.

In the foregoing paper the writer has confined his remarks to the actual experiments undertaken on the Midland Railway and the results obtained from them, without attempting to describe the various plans that have been tried in this country for burning coal in locomotives; but he would observe in conclusion that great credit is due to Mr. McConnell and Mr. Beattie for the introduction of their coal-burning engines, which created a desire for enquiry into the subject that has ultimately led to the satisfactory accomplishment of coal-burning in locomotive engines.

TABLE II

Average Results of Experiments.

Evaporative Power of different descriptions of Coal and Coke in Locomotive Engines.

Nos. of Experiments.	District.	Description of Fuel.	Distance run.	Fuel consumed.		Water evaporated.		Percentage of Ashes and Slag.	Pressure of Steam per square inch.
				Total.	Per mile.	Total.	Per lb. of fuel.		
Nos.		COAL.	Miles.	lbs.	lbs.	lbs.	lbs.	Per cent.	lbs.
1–11	Derbyshire.	Staveley Coal	1408	68,824	48·9	473,481	6.9	4·7	99
12–14		Staveley Coal	438	11,312	25·8	73,593	6·5	6·1	85
15–22		Beggarlee Coal	1024	54,544	53·3	360,849	6·6	4·5	106
23–25		Pentrich Coal	384	10,136	26·4	67,329	6·6	5·6	106
26–29		Grassmoor Coal	477	24,864	52·1	160,639	6·5	8·4	97
30–32		Babbington Coal	384	20,384	53·1	131,694	6·5	9·4	92
33–34		Molyneux Coal	256	14,336	56·0	92,341	6·4	11·3	75
35–38		Portland Coal	538	13,160	24·5	85·031	6·5	5·5	81
39–42		Shipley Coal	484	12,320	25·5	80,635	6·5	9·9	77
43–48		Wingerworth Coal	816	23,380	28·7	154,379	6·6	5·8	85
49–50		Riddings Coal	318	9,744	30·6	62,673	6·4	4·8	78
51–56		Shire Oak Coal	888	18,981	21·4	133,185	7·0	6·8	105
57–58	Durham.	St. Helen's Coal	256	12,656	49·4	96,922	7·7	4·9	96
59–61		Kepaier Coal	425	16,016	37·7	121,005	7·6	4·3	107
62–63	South Yorkshire.	Edmund's Main Coal	220	5,264	23·9	41,110	7·8	4·7	79
64–67		Kilnhurst Coal	440	11,200	25·5	85,096	7·6	5·3	81
68–69	Leicestershire.	Ibstock Coal	220	5,628	25·6	36,798	6·5	7·0	82
70–73		Swadlincote Coal	472	14,266	30·2	90,281	6·3	4·8	81

74–77	South Staffordshire.	Lord Ward's Coal	484	11,746	24·3	69,707	5·9	8·7	86
78–80		Lord Ward's Coal	384	18,480	48·1	123,274	6·7	5·5	103
81–85	Forest of Dean.	Forest of Dean Coal	640	32,816	51·3	228,040	6·9	7·4	100
86–88	Bristol.	Yate Coal	384	19,712	51·3	150,722	7·6	6·7	105
89		Kingswood Coal	128	6,720	52·5	48,078	7·2	8·3	72
90–93	South Wales.	Aberdare Coal	521	21,504	41·3	180,866	8·4	7·4	95
94–99		Rhondda Valley Coal	888	16,658	18·8	129,765	7·8	8·2	105
		COKE.							
100–102	Derbyshire.	Tapton Coke	384	24,052	62·6	170,501	7·1	...	97
103–104		Tapton Coke	296	6,772	22·9	52,580	7·8	...	61
105–107		Staveley Coke	444	11,144	25·1	75,414	6·8	...	92
108–109		Staveley Coke	200	9,426	47·1	63,562	6·7	9·7	94
110–116	Durham.	Brancepeth Coke	896	49,723	55·5	399,646	8·0	...	94
117–118		Brancepeth Coke	296	7,244	24·5	54,492	7·5	...	79
119–127		Pease's West Coke	1152	64,268	55·8	507,711	7·9	...	96
128–129		Pease's West Coke	296	6,692	22·6	53,350	8·0	...	73
		STATIONARY ENGINE.							
130–141	Derbyshire.	Staveley Coal		62,440	...	420,275	6·7	4·9	50
142–147	Durham.	Brancepeth Coke		30,128	...	219,681	7·3	4·6	50
148–153		Pease's West Coke		26·824	...	203,299	7·6	6·4	50
154–159		Mixed Coal and Coke		27,160	...	190,187	7·0	4·4	50

TABLE III.

Details of Experiments.

Evaporative Power of different descriptions of Coal and Coke in Locomotive Engines.

No. of Experiment.	Date.	Description of Fuel.	Number and Description of Engine.	Total Area of Heating Surface.	Distance run.	Fuel consumed.		Water evaporated.		Percentage of Ashes and Slag.	Average Pressure of Steam per square inch.	Remarks.
						Total.	Per mile.	Total.	Per lb. of Fuel.			
No.			Locomotive.	Sq. Ft.	Miles.	lbs.	lbs.	lbs.	lbs.	P. c.	lbs.	
1	1858	Staveley Coal	393 Goods	1131	128	6944	54·2	43880	6·3	4·8	102	
2	,,	,, ,,	,,	,,	128	5824	45·5	40447	6·9	5·4	101	
3	,,	,, ,,	,,	,,	128	5488	42·9	42736	7·7	5·3	101	
4	,,	,, ,,	,,	,,	128	6272	49·0	38539	6·1	4·7	96	
5	,,	,, ,,	,,	,,	128	6720	52·5	47698	7·1	5·0	100	
6	,,	,, ,,	,,	,,	128	6272	49·0	42354	6·7	3·8	99	Made steam well.
7	,,	,, ,,	,,	,,	128	6160	48·1	41540	6·7	5·2	98	
8	,,	,, ,,	,,	,,	128	6272	49·0	46552	7·4	4·5	100	
9	,,	,, ,,	,,	,,	128	6356	49·6	41591	6·5	4·4	98	
10	,,	,, ,,	,,	,,	128	5796	45·2	41973	7·2	5·1	96	
11	,,	,, ,,	,,	,,	128	6720	52·5	46171	6·8	4·0	100	
12	1859	Staveley Coal	14 Pass.	789	120	3080	25·6	19689	6·3	6·1	...	
13	,,	,, ,,	,,	,,	120	3192	26·6	20843	6·5	6·1	84	Made steam well.
14	,,	,, ,,	,,	,,	198	5040	25·4	33061	6·5	6·1	87	
15	1858	Beggarlee Coal	393 Goods	1131	128	5264	41·1	33578	6·3	5·3	104	
16	,,	,, ,,	,,	,,	128	7672	59·9	50249	6·5	4·8	94	
17	,,	,, ,,	,,	,,	128	7112	55·6	41210	5·8	3·3	101	
18	1859	,, ,,	,,	,,	128	6944	54·2	45407	6·5	5·7	110	Made steam well.
19	,,	,, ,,	,,	,,	128	6496	50·7	46552	7·1	5·0	106	
20	,,	,, ,,	,,	,,	128	7056	55·1	49223	6·9	4·2	110	
21	,,	,, ,,	,,	,,	128	7056	55·1	46552	6·6	4·2	109	
22	,,		,,	,,	128	6944	54·2	48078	6·9	3·7	112	

23	1859	Pentrich Coal	39 Pass.	1080	120	3248	27·0	22137	6·8	5·6	107	Made steam well.
24	,,	,, ,,	,,	,,	120	3360	28·0	21706	6·4	5·6	110	
25	,,	,, ,,	131 Pass.	1097	144	3528	24·5	23486	6·6	5·6	100	
26	1859	Grassmoor Coal	393 Goods	1131	128	7392	57·7	47693	6·4	8·3	90	Burnt with white ash; much clinker and dirt.
27	,,	,, ,,	,,	,,	128	6272	49·0	35868	5·7	8·8	95	
28	,,	,, ,,	419 Goods	,,	128	6384	49·8	46934	7·3	9·3	100	
29	,,	,, ,,	,,	,,	93	4816	51·4	30144	6·2	7·1	105	
30	1859	Babbington Coal	393 Goods	1131	128	6018	47·2	40828	6·7	9·4	90	Much dirt and clinker.
31	,,	,, ,,	,,	,,	128	7840	61·2	49604	6·3	9·4	100	
32	,,	,, ,,	,,	,,	128	6496	50·7	41262	6·3	9·4	85	
33	1859	Molyneux Coal	393 Goods	1131	128	7056	55·1	45026	6·3	11·3	65	Much dirt.
34	,,	,, ,,	,,	,,	128	7280	56·8	47315	6·4	11·3	85	
35	1859	Portland Coal	14 Pass.	789	100	2576	25·7	16187	6·2	5·5	81	Made steam well.
36	,,	,, ,,	,,	,,	120	2800	23·3	17823	6·3	5·5	81	
37	,,	,, ,,	,,	,,	120	2800	23·3	18823	6·7	5·5	80	
38	,,	,, ,,	,,	,,	198	4984	25·1	32198	6·4	5·5	83	
39	1859	Shipley Coal	4 Pass.	789	98	2618	27·7	17250	6·5	9·9	71	Much smoke and clinker.
40	,,	,, ,,	,,	,,	144	3598	24·9	22424	6·2	9·9	80	
41	,,	,, ,,	,,	,,	98	2520	25·7	16243	6·4	9·9	82	
42	,,	,, ,,	,,	,,	144	3584	24·8	24718	6·8	9·9	75	
43	1859	Wingerworth Coal	7 Pass.	789	120	3220	26·8	19836	6·2	10·0	84	Made steam well.
44	,,	,, ,,	14 Pass.	,,	198	5376	27·1	37085	6·9	4·4	81	
45	,,	,, ,,	,,	,,	100	3024	30·2	19549	6·5	5·3	85	
46	,,	,, ,,	,,	,,	100	3248	32·4	20268	6·2	5·1	88	
47	,,	,, ,,	,,	,,	100	2856	28·5	17537	6·1	5·1	84	
48	,,	,, ,,	,,	,,	198	5656	28·5	40104	7·1	5·1	86	
49	1859	Riddings Coal	14 Pass.	789	198	5712	28·8	36799	6·4	4·8	79	Much smoke; burnt fast.
50	,,	,, ,,	,,	,,	120	4032	33·6	25874	6·4	4·8	78	
51	1860	Shire Oak Coal	131 Pass.	1097	148	3152	21·3	22325	7·1	8·6	105	Made steam moderately.
52	,,	,, ,,	,,	,,	148	3140	21·2	22130	7·0	5·8	105	
53	,,	,, ,,	,,	,,	148	3224	21·8	22705	7·0	6·0	105	
54	,,	,, ,,	,,	,,	148	3073	20·8	21375	6·9	7·8	105	
55	,,	,, ,,	,,	,,	148	3058	20·7	21185	6·9	8·1	105	
56	,,	,, ,,	,,	,,	148	3334	22·5	23465	7·0	4·5	105	

No. of Experiment.	Date.	Description of Fuel.	Number and Description of Engine.	Total Area of Heating Surface.	Distance run.	Fuel consumed. Total.	Fuel consumed. Per mile.	Water evaporated. Total.	Water evaporated. Per lb. of fuel.	Per centage of Ashes and Slag.	Average Pressure of Steam per square inch.	Remarks.
No.			Locomotive.	Sq. Ft.	Miles.	lbs.	lbs.	lbs.	lbs.	P. c.	lbs.	
57	1859	St. Helen's Coal	393 Goods	1131	128	6496	50·7	48841	7·5	3·4	98	Made steam well; but much smoke.
58	,,	,, ,,	,,	,,	128	6160	48·1	48081	7·8	6·4	95	
59	1859	Kepaier Coal	393 Goods	1131	128	5040	41·0	37394	7·4	3·0	105	
60	,,	,, ,,	,,	,,	128	4928	38·5	37776	7·6	5·0	109	
61	,,	,, ,,	,,	,,	169	6048	35·7	45835	7·5	4·8	...	
62	1859	Edmund's Main Coal	14 Pass.	789	120	2800	23·3	22567	8·5	4·7	80	Much smoke and small coal.
63	,,	,, ,,	,,	,,	100	2464	24·6	18543	7·5	4.7	79	
64	1860	Kilnhurst Coal	14 Pass.	789	100	2464	24·6	18256	7·4	5·3	83	
65	,,	,, ,,	,,	,,	120	3024	25·2	24436	8·0	5·3	82	
66	,,	,, ,,	,,	,,	120	3192	26·6	24005	7·5	5·3	80	
67	,,	,, ,,	,,	,,	100	2520	25·2	18399	7·3	5·3	80	
68	1859	Ibstock Coal	14 Pass.	789	100	2576	25·7	16674	6·4	7·0	83	Made steam badly; much ashes and dirt.
69	,,	,, (*Staveley Coal)	,,	,,	120	[2912 *140]	25·4	20124	6·5	7·0	81	
70	1859	Swadlincote Coal	14 Pass.	789	100	3024	30·2	17681	5·8	4·8	85	Made steam badly.
71	,,	,, ,,	,,	,,	120	3920	32·6	25011	6·3	4·8	78	
72	,,	,, ,,	,,	,,	132	3752	28·4	24303	6·4	4·8	80	
73	,,	,, ,,	,,	,,	120	3570	29·7	23286	6·5	4·8	82	
74	1859	Lord Ward's Coal	7 Pass.	789	98	2520	25·7	15087	5·9	8·7	90	Burnt fast; much ashes and dirt.
75	,,	,, ,,	,,	,,	144	3486	24·2	20123	5·7	8·7	82	
76	,,	,, ,,	,,	,,	98	2282	23·2	13655	5·9	8·7	85	
77	,,	,, ,,	,,	,,	144	3458	24·0	20842	6·0	8·7	89	
78	1859	Lord Ward's Coal	419 Goods	1131	128	5712	44·7	40446	7·0	6·2	105	
79	,,	,, ,,	,,	,,	128	6608	51·6	42736	6·4	4·7	100	
80	,,	,, ,,	,,	,,	128	6160	48·1	40092	6·5	5·6	103	

81	1859	Forest of Dean Coal	393 Goods	1131	128	7056	55·1	53277	7·5	7·4	103	Made steam badly; clinker, and much smoke.
82	,,	,, ,,	,,	,,	128	5600	43·7	38158	6·8	6·6	93	
83	,,	,, ,,	,,	,,	128	7168	56·0	48460	6·7	6·4	103	
84	,,	,, ,,	,,	,,	128	6048	47·2	40066	6·6	8·8	103	
85	,,	,, ,,	,,	,,	128	6944	54·2	48079	6·9	7·7	100	
86	1859	Yate Coal	393 Goods	1131	128	6496	50·7	51894	7·6	6·7	106	Made steam moderately; much clinker and ashes.
87	,,	,,	,,	,,	128	6384	49·8	49605	7·7	7·0	108	
88	,,	,,	,,	,,	128	6832	53·3	49223	7·2	6·5	99	
89	1859	Kingswood Coal	393 Goods	1131	128	6720	52·5	48078	7·1	8·3	72	Made steam badly.
90	1859	Aberdare Coal	393 Goods	1131	128	5376	42·0	44644	8·3	7·6	100	Made steam well; little smoke, but clinker.
91	,,	,, ,,	,,	,,	128	4368	34·1	36249	8·3	7·4	90	
92	,,	,, ,,	,,	,,	162	6720	41·4	59526	8·8	7·4	90	
93	,,	,, ,,	,,	,,	103	5040	48·9	40447	8·0	7·3	100	
94	1860	Rhondda Valley Coal	131 Pass.	1097	148	2686	18·1	21375	7·9	7·7	105	Made steam moderately; little smoke, but clinker.
95	,,	,, ,,	,,	,,	148	2352	15·8	19000	8·0	9·1	105	
96	,,	,, ,,	,,	,,	148	2772	18·7	21280	7·6	6·9	105	
97	,,	,, ,,	,,	,,	148	2688	18·1	21940	8·1	9·5	105	
98	,,	,, ,,	,,	,,	148	2800	18·9	21470	7·6	7·2	105	
99	,,	,, ,,	,,	,,	148	3360	23·7	24700	7·3	9·1	105	
100	1853	Tapton Coke	265 Goods	1146	128	8512	66·5	63369	7·4	...	100	Made steam well with clean fire, but much clinker.
101	,,	,, ,,	,,	,,	128	7812	61·0	56957	7·2	...	100	
102	,,	,, ,,	227 Goods	1050	128	7728	60·3	50175	6·5	...	90	
103	1853	Tapton Coke	135 Pass.	1097	148	3360	22·7	25296	7·5	...	71	
104	,,	,, ,,	,,	,,	148	3412	23·0	27284	7·9	...	52	
105	1855	Staveley Coke	131 Pass.	1097	148	3472	23·4	24916	7·1	...	91	
106	,,	,, ,,	,,	,,	148	3464	23·2	23489	6·8	...	91	
107	,,	,, ,,	,,	,,	148	4208	26·9	27009	6·6	...	93	
108	1855	Staveley Coke	371 Goods	1155	100	4386	43·8	30844	7·0	9·7	93	
109	,,	,, ,,	,,	,,	100	5040	50·4	32718	6·4	9·7	95	

No. of Experiment.	Date.	Description of Fuel.	Number and Description of Engine.	Total Area of Heating Surface.	Distance run.	Fuel consumed. Total	Fuel consumed. Per mile.	Water evaporated. Total.	Water evaporated. Per lb. of fuel.	Percentage of Ashes and Slag.	Average Pressure of Steam per square inch.	Remarks.
No.			Locomotive.	Sq. Ft.	Miles.	lbs.	lbs.	lbs.	lbs.	P. c.	lbs.	
110	1853	Brancepeth Coke	265 Goods	1146	128	8848	69·1	73648	8·3	...	100	
111	,,	,, ,,	,,	,,	128	7500	58·6	63275	8 4	...	90	
112	,,	,, ,,	,,	,,	128	6020	47·0	49601	8·2	...	100	
113	,,	,, ,,	,,	,,	128	5990	46·8	47904	7·9	...	100	Made steam well.
114	,,	,, ,,	,,	,,	128	6945	54·2	57173	8·2	...	100	
115	,,	,, ,,	227 Goods	1050	128	6580	51·4	50248	7·6	...	85	
116	,,	,, ,,	,,	,,	128	7840	61·2	57797	7·3	...	85	
117	1853	Brancepeth Coke	135 Pass.	1097	148	3304	22·3	23775	7·1	...	87	
118	,,	,, ,,	,,	,,	148	3940	26·6	30717	7·7	...	72	
119	1853	Pease's West Coke	265 Goods	1146	128	8176	63·8	66953	8·1	...	95	
120	,,	,, ,,	,,	,,	128	8540	66·7	67801	7·9	...	100	
121	,,	,, ,,	,,	,,	128	7168	56·0	55448	7·7	...	95	
122	,,	,, ,,	,,	,,	128	6244	48·7	50261	8·0	...	100	
123	,,	,, ,,	,,	,,	128	6608	51·6	54222	8·2	...	100	
124	,,	,, ,,	,,	,,	128	5880	45·9	49036	8·3	...	100	Made steam well.
125	,,	,, ,,	,,	,,	128	6832	53·3	55639	8·1	...	100	
126	,,	,, ,,	227 Goods	1050	128	7448	58·1	53756	7·2	...	85	
127	,,	,, ,,	,,	,,	128	7372	57·5	54595	7 4	...	85	
128	1853	Pease's West Coke	135 Pass.	1097	148	3080	20·8	23679	7·7	...	80	
129	,,	,, ,,	,,	,,	148	3612	24·4	29671	8·2	...	66	

130	1856	Staveley Coal	Stationary engine; chimney draught and slow combustion.	1125	...	5488	...	36887	6·7	6·1	50	Made steam well.
131	,,	,, ,,		,,	...	5600	...	37981	6·7	6·4	50	
132	,,	,, ,,		,,	...	5768	...	38712	6·7	6·4	50	
133	,,	,, ,,		,,	...	5488	...	32712	6·8	6·4	50	
134	,,	,, ,,		,,	...	5600	...	39168	6·9	3·6	50	
135	,,	,, ,,		,,	...	4032	...	27687	6·8	3·6	50	
136	,,	,, ,,		,,	...	5600	...	37893	6·7	4·4	50	
137	,,	,, ,,		,,	...	4704	...	33156	7·0	4·4	50	
138	,,	,, ,,		,,	...	5600	...	38618	6·8	4·4	50	
139	,,	,, ,,		,,	...	5376	...	36437	6·7	4·4	50	
140	,,	,, ,,		,,	..	5600	...	36981	6·6	4·4	50	
141	,,	,, ,,		,,	...	3584	...	24043	6·1	4·4	50	
142	1856	Brancepeth Coke		1125	...	5656	...	38256	6·7	5·7	50	Made steam well.
143	,,	,, ,,		,,	...	5264	...	40262	7·6	4·2	50	
144	,,	,, ,,		,,	...	5320	...	38048	7·3	4·2	50	
145	,,	,, ,,		,,	...	5712	...	42262	7·3	3·8	50	
146	,,	,, ,,		,,	...	4928	...	36628	7·4	3·8	50	
147	,,	. ,,		,,	...	3248	...	24225	7·4	5·9	50	
148	1856	Pease's West Coke		1125	...	4480	...	35525	7·9	7·3	50	Made steam well.
149	,,	,, ,,		,,	...	5096	...	38075	7·4	7·3	50	
150	,,	,, ,,		,,	...	4816	...	34975	7·2	7·2	50	
151	,,	,, ,,		,,	...	4760	...	35525	7·4	7·2	50	
152	,,	,, ,,		,,	...	4648	...	35156	7·5	4·7	50	
153	,,	,, ,,		,,	...	3024	...	24043	7·9	4·7	50	
154	1856	Mixed { Half Staveley Coal and Half BrancepethCoke		1125	...	4816	...	32975	6·8	4·4	50	Made steam well.
155	,,	,,		,,	...	4760	...	33156	6·9	4·4	50	
156	,,	,,		,,	...	4928	...	33700	6·8	4·4	50	
157	,,	,,		,,	...	4704	...	32975	7·0	4·4	50	
158	,,	,,		,,	...	4760	...	33881	7·1	4·4	50	
159	,,	..		,,	...	3192	...	23500	7·3	4·4	50	

Mr. B. Fothergill fully agreed in the economy of burning coal instead of coke in locomotive engines; and the results stated in the paper were thoroughly confirmed by those obtained in a series of experiments he had made on the Lancashire & Yorkshire and East Lancashire Railways, which were so strongly in favour of coal that there were now no coke-burning engines on those lines. In those experiments it was found that the evaporative power of coal and coke was about the same, weight for weight, so that for conveying the same load, the same weight of coal was sufficient as of coke; and the average cost of the coal used being only about 5*s.* 3*d.* to 5*s.* 6*d.* per ton while that of coke was 11*s.* to 11*s.* 6*d.* per ton, the saving effected by the substitution of coal amounted to as much as half the entire cost of fuel previously consumed. The admission of air was regulated by a slide over airholes in the back of the firebox, and a deflecting plate was fixed underneath the tubes; a deflecting plate and brick arch in the firebox had also been employed. When the deflecting plate was used alone without the brick arch, there was a bright part in the centre of the fire at the point where the current of air was directed by the plate; but in front and at the back was a black column of smoke from the coal, and that in front escaped direct into the tubes: but by adding the arch the smoke was all thrown back into the bright centre of the fire, and thus completely consumed before entering the tubes, so that no smoke issued from the chimney. He had not the least doubt that perfect combustion of the smoke could be effected by this means in ordinary engines with burning coal. The brick arch had also the advantage of preventing the blast from plucking away particles of the fuel unconsumed into the lower tubes, which not only occasioned a waste of fuel, but also had the effect of wearing away the tubes rapidly by the cutting action of the hard particles. The use of coal had also been adopted practically for some years on the London and South Western Railway, in engines constructed specially for the purpose.

Mr. F. Wrigley considered it was certainly the right plan to deflect the air downwards on the fire, to prevent its passing across direct from the firedoor into the tubes: but if the deflecting plate were confined to the width of the door, it would concentrate the air entirely on the middle part of the fire, while smoke would still be

given off at the sides; and with the firedoor made to slide horizontally in two portions as shown in the drawing, the air would be cut off at the sides when the door was partially closed, leaving a thin sheet of air entering in the centre only. He thought therefore it would be a better plan to make the firedoor opening extend wider across the firebox, and the door to slide vertically instead of horizontally, so as to direct the air always over the entire width of the fire.

The CHAIRMAN observed that a wider firedoor would weaken the back of the firebox too much, and would be objectionable in obstructing the steam rising from the water space below the door.

Mr. MARKHAM said in first trying the long deflecting plate in the firebox the proper length and inclination of the plate had to be determined : when the end of the plate was raised above the level of the bottom rows of tubes, a quantity of air passed over the fire direct into the tubes without causing the smoke to be properly consumed ; and it was found by experiment that the air should be deflected on to the surface of the fire in the manner shown in the drawings. The long deflecting plates were very little trouble or expense to maintain; for though they burnt away at the ends in time, they lasted in passenger engines from two to four months and in goods engines about half that time before wanting repair, and fresh ends were then easily rivetted on: the plates were quite loose in their place, being merely held in the opening of the firedoor by the flange and by their own weight. It was important that the deflecting plate should be lifted out of the firebox with the shovel when the firedoors had to be closed up at the end of the day's work, when the coal had become thoroughly coked, otherwise it would soon be destroyed by the heat. The addition of the firebrick arch was an improvement by preventing the smoke from entering the tubes, and compelling it to pass back through the hottest part of the firebox before reaching the tubes, whereby it was more perfectly consumed. The brick arches as shown in the drawing were expected to last for nine months before requiring to be renewed: they were composed of only two patterns of bricks, the side bricks being made of such a shape as to be used at either side of the firebox. The firedoors now in use on the Midland Railway, 18 inches wide by 11 inches high, proved sufficient for admitting the quantity of air required to consume the

smoke: the doors were generally kept wide open, and the ashpan damper which had previously been kept wide open so as to give 3 square feet area of opening was now opened to only about 1 square foot area, by far the larger proportion of air being admitted above the fire through the firedoor. There was not professed to be any very remarkable originality in the plan described in the paper for burning coal in locomotives: but the long deflecting plate, the large area of firehole with the sliding doors, combined with the firebrick arch and steam jet, as now adopted on the Midland Railway and shown in the drawings, were the result of the large number of experiments that he had made. The plan of deflecting the air upon the surface of the fire had been introduced many years ago: but the plan of burning the coal from the surface downwards had never been attempted to such an extent previously, and he was satisfied it would ultimately be generally adopted where coal was used as fuel in locomotives.

Mr. D. Adamson was surprised at the evaporative duty of coal burnt in locomotive engines being so low as 6 lbs. of water per lb. of coal, and thought this must be owing to want of sufficient room for combustion. With Lancashire coal he had found that the duty obtained in a stationary boiler was much increased by elongating the firebox and shortening the tubes, and had gradually lengthened the firebox from 12 to 24 feet, shortening the tubes to only 4 feet length; the duty was formerly only 6½ lbs. of water evaporated per lb. of coal, but was now raised by the long firebox to 9½ lbs., including lighting the fire and getting up steam: but he was satisfied there was still a great deal to be done to increase the economical consumption of coal in engine boilers. He thought there was little advantage in the great length of tubes at present employed in locomotive engines; for the old engines running on the Stockton and Darlington Railway with flue boilers evaporated as much water with 1 lb. of coal as modern engines with 1 lb. of coke, which he attributed to their having 12 to 14 feet length of combustion chamber in the flue. He doubted whether the firebrick arches were worth putting in, and thought it would be better to shorten the tubes and prolong the firebox into the boiler so as to give more room for combustion. For admitting air to the fire in coal-burning engines a plan of hollow stays at the sides and front of the

firebox just above the level of the fire had been tried, to admit the air at the surface of the fire; and he believed this had proved an advantage in preventing smoke, particularly the holes in front of the box, through which a strong current of air entered when the engine was running.

Mr. B. Fothergill had no doubt an advantage would be gained in increasing the surface of the firebox and the space for combustion, by carrying the box forward a short distance into the boiler; but considered it was not advisable to shorten the tubes in locomotive engines, because with short tubes there was risk of a deposit of unconsumed particles of coal in the smokebox, which would catch fire and might heat the smokebox red-hot, warping the plates of the box and allowing cold air to enter. He thought it was desirable in locomotives to approach as slow a combustion as in stationary engines, whereby a greater duty would be obtained from the fuel; but if the combustion were so much forced as to require a steam jet to prevent smoke, a great amount of heat must escape up the chimney, as there was not time enough for it to be thoroughly taken up by the boiler. In the results that he had obtained as to evaporative duty in burning coal in locomotive engines, $6\frac{1}{4}$ lbs. of water per lb. of coal was the lowest duty and $9\frac{1}{2}$ lbs. the highest in an exceptional case; the general average might be taken at about 7 lbs.

Mr. Markham had been surprised at the low evaporative results obtained in burning coal, for it had been said that the evaporative duty of the Derbyshire coal was 10 lbs. of water per lb. of coal; but he thought there must have been priming in these cases, carrying over water with the steam and causing an excess in the result, as he had the greatest confidence in the general accuracy of the experiments detailed in the paper. As regarded slow or rapid combustion, he was satisfied this did not make any material difference, if the quantity of air was increased to suit the rapidity of combustion; for it was seen from the experiments that as much water was evaporated in a goods engine with quick combustion as in the stationary boiler with a chimney draught and slow combustion. The late Mr. Robert Stephenson considered a moderate sized firebox better than a large one for coke-burning engines, because the heat was more intense and concentrated; and there must

be an advantage he thought in having a high temperature, as in Bury's early engines, which had very small fireboxes and an iron bar put into the firebox was drawn out at a white heat: but in the present engines with large fireboxes the same degree of heat could not be obtained. There was no doubt that an inferior quality of fuel rendered an increased area of firegrate surface necessary for consuming the required quantity of fuel in a given time.

Mr. E. A. Cowper observed that with the hollow stays in the sides of the firebox for the admission of air had been combined a plan of having a jet of steam in the centre of each hole, which had the effect of forcing in the air upon the top of the fire; and by applying these jets in front of the firebox the brick arch might be done away with. The plan had the advantage that in stopping at a station the steam jet was kept on in the firebox, while the dampers were closed, and the steam then damped down the fire and supplied air enough to burn the smoke; but a steam jet in the chimney increased the draught through the fire and drew off the smoke unconsumed through the tubes, making the smoke rather worse than without the jet.

The Chairman believed the difficulty with a steam jet had been in keeping up the supply of steam in the boiler when there was such a constant drain upon it. He thought for burning the smoke efficiently it was necessary to have a thoroughly attentive driver, without which no plan could be successful; he had seen all the plans at work that had been referred to, and was satisfied that coal might be burnt in locomotives without any nuisance from smoke. He considered the plan adopted on the Midland Railway both simple and efficient.

He proposed a vote of thanks to Mr. Markham for his paper, which was passed.

The Meeting was then adjourned to the next day. In the afternoon a number of the principal manufacturing establishments in the town and neighbourhood were opened to the inspection of the Members.

In the evening the Members and their friends were invited by the Local Committee to a Conversazione in the Town Hall, where a collection of engineering models, machinery, drawings and photographs, philosophical instruments, microscopes, and works of art, were exhibited. The engineering models included a collection of the original models made by James Watt, lent from the Soho Foundry, and on this occasion for the first time publicly exhibited: comprising the original condenser and steam cylinder with which Watt made his first experiments in condensing steam, and a series of substitutes for the crank motion, models of the original direct-acting and beam pumping engines, ore-crushing machine, tilt hammer, indicator, and pump counter. Models were also shown of Murdoch's first slide-valve engine, and oscillating engine, and his original small locomotive engine. A specimen of the Armstrong rifled ordnance, lent by the War Department for the occasion, was exhibited; and a collection of small arms, lent from the museum of the Midland Institute.

The Adjourned Meeting of the Members was held in the Lecture Theatre of the Midland Institute, Birmingham, on Thursday, 9th August, 1860; James Kennedy, Esq., President, in the Chair.

The following paper was read:—

DESCRIPTION OF AERTS' WATER AXLEBOX.

By Mr. SAMPSON LLOYD, of Wednesbury.

The attention of engineers and carriage builders has been constantly directed to improvements in railway axleboxes, as shown by the various contrivances that have been invented for the purpose. These however have all included the use of oleaginous matter as a lubricator, though it is well known there is an inherent defect attached to such a material, since the brass bearing must be heated by the friction of the journal before the grease can be brought down to lubricate the bearing. If a perfect lubricator for railway axles could be obtained, it would effect a great saving both of tractive power and also of commercial cost, as compared with a material that performs its duty in an imperfect manner. The essential conditions for a good method of lubrication are—first, there should be a constant and abundant supply of a pure lubricating fluid; and secondly, the working parts should be always kept free from foreign substances, the tendency of which is to increase the friction or to intercept the free contact of the lubricating material with the bearing surfaces. These conditions are successfully fulfilled in the simple construction of axlebox now about to be described; the principal feature of which is the use of water as the lubricator, in place of oil or grease which has generally been used on railways, thus avoiding the many inconveniences that have resulted from the use of fatty substances.

The Water Axlebox, which is the invention of M. Aerts of Belgium, is shown in Figs. 1, 2, and 3, Plate 36; Fig. 1 is a longitudinal section of a railway axlebox, Fig. 2 a transverse section at the front part of the box, and Fig. 3 a transverse section at the centre. On the end of the axle a cast iron disc A is firmly fixed, working in a reservoir of water B. When the carriage moves, the disc turning round with

the axle raises the water by the centrifugal force of its rotation into the upper part of the axlebox, where it is caught by the brass scraper C resting loosely on the top of the disc, and is discharged into the inclined spout D, which conducts it directly over the axle, and thus lubricates the bearing completely and continuously. The lubrication thus commences as soon as the carriage is put in motion, and the quantity of water lubricating the bearing is increased in proportion to the velocity of rotation, since the faster the disc turns the greater is the quantity of water carried up with it.

The joint at the back of the axlebox is made by a cast iron collar E, shown enlarged to half full size in Fig. 4, Plate 36, keyed on the axle immediately behind the journal; it is turned accurately on the outside and runs within a leather collar F, shown black in the drawings, that is made to be just a fit upon it; this leather collar is rivetted inside the annular cast iron disc G, and is kept always close upon the collar by the slight pressure of a small india-rubber band or steel spring I surrounding it. In order to prevent leakage of water between the leather F and the cast iron collar E, where the friction takes place in running, the flange of the collar E is made of a conical form, and the inner side of the disc G is similarly shaped, as shown in Fig. 4, so that by the rotation of the collar E the water is thrown away from the joint by centrifugal force, and returned into the axlebox. The disc G is held up against the back of the axlebox by the outside back plate H, Fig. 1, and has a thick india-rubber ring K let into a groove in its face, which presses against the back of the axlebox and forms a water-tight joint; allowing for the box coming down as the brass wears, and at the same time affording sufficient elasticity to admit of a slight play of the disc within the space at the back of the box whilst running. When the axleboxes are well fitted and the joint at the back properly made, as shown in Fig. 4, there is no leakage of water, and the level of the water does not perceptibly vary during a long time of running, since that which has lubricated the axle returns into the reservoir B in the lower part of the box; and the amount of evaporation of the water is in practice so small as to be scarcely appreciable.

With the ordinary method of lubrication, if an axle gets heated it is cooled by throwing water on it; but in the water axlebox the water

being poured over the axle in a continuous stream effectually prevents it from heating. Water has also the advantage of allowing all solid particles to sink to the bottom of the reservoir; but where grease is used they remain mixed with it, and thus become the chief source of wear and heating of the bearing. In order to clean the reservoir B it is only necessary to unscrew the plug L in the lower part of the box, which allows the dirty water to run out; and by means of a syringe, such as is used in cleaning the carriages, the reservoir can be thoroughly rinsed through; the screw is then replaced, and a supply of fresh water poured into the box through the lid M. This process is therefore neither difficult nor expensive in the water axlebox; while with the ordinary grease box, when it gets out of order, the carriage must be raised and the bolts of the box unfastened, which requires considerable time and the attendance of several workmen. If the reservoir B should accidentally be omitted to be filled with water, or if by any means the water should run out of the box, there is still an ordinary grease box N as a reserve to fall back upon, which will come into use on an emergency, the upper part of the box containing a supply of grease like an ordinary axlebox; but as the waste of water is so very small, such a case is not likely to occur when proper care is exercised.

Figs. 5 and 6, Plate 37, show the application of the same method of lubrication by water to the bearings of shafting; Fig. 5 being a transverse section, and Fig. 6 a longitudinal section. In this case the disc A for raising the water as the shaft revolves is made in two halves fastened together by lugs, and fixed on the shaft by a set screw or key; the water carried up is caught by the scraper C, which discharges it direct upon the top of the bearing.

Before fixing the water axleboxes in place the brass bearing and axle are both well greased, so as to prevent oxidation of the metal by the water; while the water prevents the contact of the two metals as it passes between the two greased surfaces. In practice the grease is found to solidify after a short time of running, and forms a sort of varnish of a dark brown colour, thus proving the absence of actual contact between the two metal surfaces; for were it otherwise, the surface of the axle would become polished.

This water axlebox has been tried on the Great Northern Railway during the early part of this year, on a second class carriage having two of the bearings fitted with the water box and two with the ordinary grease box used on that line. The result of five weeks' running over a total distance of 9819 miles was that the brass bearings of the water axleboxes were not found to be diminished in weight, while the bearings of the grease boxes had lost together 1½ ounces; and the water boxes ran 7326 miles without requiring to be replenished with water. Trials of the water axleboxes have also been made on the Eastern Counties Railway during the past and the present years: the two bearings of one axle in a first class carriage of an express train were fitted with the water axleboxes, and those of the other axle with the ordinary grease boxes; after running a total distance of 11,249 miles during two months' constant working, the brasses in the ordinary boxes had lost together 30 ounces in weight, while those in the water boxes had lost together only 7 ounces, or less than one fourth, the wear of the brasses occurring principally at the shoulders of the bearings. The consumption of grease in this trial was 8½ lbs., in the two ordinary axleboxes, and in the water boxes 3 lbs. which however was all consumed on one journey and in one box, in consequence of the box having been by neglect allowed to run without water on one occasion; but no inconvenience was occasioned, as the tallow in the reserve grease chamber was quite sufficient to lubricate the bearing in the absence of the water. In a subsequent trial on another first class carriage, during two months' constant running, the water axleboxes worked remarkably well; they ran for many days a distance of 252 miles daily without requiring additional water, and were not supplied with any grease after that originally put in.

By this method of using so simple and perfect a lubricating material as water, the cost of oil or grease is saved, and it is calculated that a considerable saving of traction results from the almost total absence of friction, while the wear of the brasses and journals is reduced to a minimum; so that instead of the brasses lasting on the average only nine months, as is ordinarily the case, their time of running is greatly increased.

Mr. Lloyd showed a specimen of the water axlebox for railway carriages, and a model of its application to bearings of shafting. He had brought the subject forward because his experience of the axlebox had been very satisfactory, as regarded its application both to railway bearings and to shafting revolving at a rapid rate; and improvement in lubrication was of great importance, particularly for the axles of railway carriages, where the present cost of grease and renewal of brasses formed such a large item of expense. At Mr. Leech's mill at Staleybridge, where the water boxes had been applied, there was a large shaft that previously caused great difficulty by heating and required oiling two or three times during the day; but by applying the water boxes the shaft had now been running more than a year without any heating taking place, and no trouble had been experienced with the bearings; they continued working quite satisfactorily, the grease having formed a varnish over the bearing surfaces.

Mr. Aerts explained that the principle aimed at in the water axlebox was to have greased surfaces for the bearing, with a constant stream of water running over them, so as to interpose a film of water constantly between the rubbing surfaces, preventing contact of the two metallic surfaces and thereby removing the cause of heating. The principle of lubrication by means of water was not a new one, having previously been used for stationary bearings in mills, as in the case of the bearings of rolls; but in such instances the water was employed in a current running over the bearing to keep it cool, and was all allowed to run away; and it was therefore not applicable in that manner either for the bearings of railway carriages or for factories. In the form of railway axlebox first made, the box was made to open in front for pouring in the water, with the ordinary grease lid on the top; but this construction was rather complicated and not convenient for filling the box with water, and the opening in front allowed some leakage of water when the carriage was in motion. It was then tried to pour in the water through the top, and for this purpose the opening at top was divided into two separate parts, as shown in the drawing, both closed by the same lid, the water being poured in at the front and the grease at the back.

The most difficult part to make complete was the joint for closing in the box at the back, so as to prevent leakage of water; and in the first boxes considerable leakage took place at this point, the centrifugal force produced by the rotation causing the water to be driven up the curved shoulder of the journal and thrown right against the joint, so that the boxes would run only 110 or 120 miles, and then required a fresh supply of water to make up for the leakage. This led to fixing the cast iron collar on the axle, immediately behind the journal, having a flange raised on the end next the journal, to prevent the water being thrown off the journal against the leather collar forming the joint; the back of this flange was made of a conical form, in order that any water finding its way to the joint might be thrown off by the centrifugal force and returned into the axlebox. The leather collar within which the friction of the axle took place in running was moulded exactly to the size of the axle, and kept close upon it with a gentle pressure by an india-rubber band or steel spring outside the collar. The metal disc or plate containing the leather collar was held tight up against the back of the axlebox, with a thick india-rubber ring between, which made a water-tight joint all round; and this india-rubber ring was not exposed to any wear, as the metal plate was stationary against the back of the box. It was found desirable to allow a slight leakage of water at the leather collar where the friction took place, in order to ensure the leather being kept always moist, so as to prevent it from being worn away by getting dry and heated by the revolution of the axle; when this precaution was taken, the leather collar was found to last eight months in constant work without any wear. It was possible to run 1000 miles without any fresh supply of water to the box; but in practice it was advisable to replenish the boxes with water every day, or after running 400 or 500 miles. For emptying the water quickly out of the axlebox, the hole at the bottom of the box was now closed by an india-rubber washer held up by a spring, instead of by a screwed plug, to save time and trouble and avoid requiring any tools; the handle of the spring came up in front of the box and had a slot in it, so as to be readily fixed open for the water to run out, or closed securely when a fresh supply had been poured in.

In order to keep out the dust at the back of the box, a recess was formed on the face of the wheel boss by a projecting rim covering over the end of the leather collar; so that the joint was completely covered and protected from any access of dust. For the same purpose the hinge of the grease cover on the top of the box was made of such a form that no particles of dust should be drawn in by it into the box in opening the lid, the hinge being made to overhang the metal of the box, as shown in the drawing, so that there was no place for dust to lodge upon.

Instead of allowing a certain amount of end play in the collars of the brasses, as in ordinary axleboxes, to admit of running round curves with ease, in the new axlebox the box was allowed to play freely under the spring laterally, by means of three small rollers fitted in the underside of the spring clip; with this plan there was no noise or jolting in passing from a straight line to a curve.

Mr. W. A. Adams observed that the new axlebox appeared from its construction to be much more expensive in first cost than the ordinary boxes, and he did not see how sufficient economy could be obtained by it, either in wear of brasses or in grease, to compensate for the extra first cost. He had found ordinary brasses were not worn out in so short a time as nine months, but would run a good deal longer; and from the average of long experience in the maintenance of railway wagons, the total cost of supplying grease and attendance was covered by 13*s.* per annum per wagon, which left but a very small margin for saving to make up for the greater first cost of the water axleboxes. There would also be a difficulty he thought with water axleboxes, from the water freezing in them in cold weather, when a train of wagons had to stand in a siding where there was no one to attend to them and let the water out; the ordinary grease boxes could be left a long time without attention, and required looking to only now and then at principal stations, while they were not affected by hot or cold weather.

Mr. Aerts replied that the economy in wear of brasses was a very important point of advantage in the water axlebox, as regarded saving in working expenses; for at present the cost of repairs, including material and workmanship, greatly exceeded that of grease,

amounting to 10 times the cost of grease on the Eastern Counties Railway, and $4\frac{1}{2}$ times on the Great Northern Railway, the variation arising from differences in the circumstances of the traffic over the two lines. In the water axleboxes however the wear was reduced to a minimum, the two greased bearing surfaces being kept from actual contact by a thin film of water between, so that they acquired a varnished appearance, instead of becoming polished by friction as would otherwise be the case: and accordingly in the comparative trial that had been made on the Great Northern Railway between a pair of the water axleboxes and a pair of the ordinary grease boxes fitted on the same carriage, the brasses of the latter lost $4\frac{1}{2}$ ounces together in running nearly 10,000 miles, while there was no reduction of weight in the brasses of the water axleboxes; and in the similar trial on the Eastern Counties Railway the brasses of the ordinary grease boxes lost together 30 ounces of their weight in running about 11,000 miles, while those in the water axleboxes lost only 7 ounces together, or less than one fourth. With regard to the saving in grease, the ordinary grease boxes had now to be filled again after running only 40 or 50 miles, requiring attendants at various stations on the road; but the water axleboxes would run if necessary upwards of 1000 miles without needing a fresh supply of water, so that they would dispense with attendants on the road, and would need attendants only at terminal stations. The saving thus effected in attendance would allow of a few more men if required at the principal stations, in cold countries such as Russia or Canada, to look after wagons standing in sidings, and to let out the water from the axleboxes in frosty weather, which was quickly done by releasing the spring closing the bottom hole: but in this country is was not necessary to let the water out, and water axleboxes had been running on the Eastern Counties Railway during the past two winters, in which the water had never required to be let out to prevent freezing, nor had any difficulty been experienced from that cause.

Mr. Lloyd remarked that the advantages of the water axlebox were more particularly apparent in the case of swift passenger traffic, which at present required attention to the grease boxes of the carriages at each stopping station. The saving in cost of maintenance of brasses

would be very considerable with the new axleboxes, for on the Great Western Railway the carriage brasses lasted only about eleven months on an average; but the great reduction of friction in the water boxes was shown by their keeping quite cool in running, and he had travelled with these axleboxes and found there was no heating at all in them on the road.

Mr. C. W. Siemens thought the saving of friction in the water axlebox was a point of great importance; and it would be desirable to know what was the actual amount of friction, and whether the water in the box was warmed by it. In the ordinary grease boxes the heat had to rise sufficiently to melt down the grease, the amount of heat affording a measure of the power wasted in the process; and if the degree to which the water was warmed in the new boxes were ascertained, it would show the comparative amount of friction in them. At present a tractive power of about 8 lbs. per ton of load was required to overcome the friction of the ordinary axleboxes and the rolling friction of the wheels; and any material saving in the friction of the journals would produce an important saving in power.

Mr. Aerts said the water did not become heated in the new boxes, and this showed that there was no appreciable friction between the bearing surfaces, otherwise the grease on the journal and brass would not continue to adhere to them; but the grease did not get rubbed off in working, in consequence of the water passing constantly between.

Mr. E. A. Cowper remarked that there must inevitably be some friction between the bearings in running under the pressure of the load, which would produce a certain amount of heat, however small an amount it might be reduced to; and the small quantity of water lost from the box by evaporation was probably driven off by the heat produced in running. The heat produced might be sufficient to prevent freezing in winter while running; but if the carriages had to stand for a length of time in a siding, he feared the water would get frozen sometimes, as the water cranes at the stations would be frozen in severe weather if not kept warm by fires, and there might be some danger of the ice bursting the axlebox.

Mr. Lloyd said the grease chamber in the upper part of the water axlebox was supplied for such contingencies, and would then come into action by the heating of the bearing, which would soon remove the difficulty by thawing the frozen water.

Mr. C. W. Siemens did not think the chance of the water freezing was a serious objection to the new axlebox, or would cause any difficulty; for if it did freeze, the revolution of the disc on the end of the axle would break up the ice as soon as the carriage was put in motion; and if pieces of ice got carried up over the bearing with the water, they would not do any harm and would soon be melted.

Mr. J. Wright thought it would be an advantage in the water axlebox if the cast iron collar fixed on the axle at the back of the box could be dispensed with, since it would be an objection in changing a pair of wheels if any special fitting of that kind upon the axle were required, and would prove a hindrance to the adoption of the box. The same objection had been experienced in the case of previous plans of axleboxes, which required some special form of axle to fit them; and though it would not be felt where the entire rolling stock of a railway was furnished with the new axleboxes, great inconvenience would arise where they were used upon only a portion of the carriages.

The Chairman proposed a vote of thanks to Mr. Lloyd and Mr. Aerts, which was passed.

The following paper was then read:—

ON A NEW PROCESS OF OPEN COKING.

By Mr. SAMUEL H. BLACKWELL, of Dudley.

All coals divide themselves into one of two classes, bituminous and anthracitic. The first class is again subdivided into caking and non-caking coal. It is only these two varieties of bituminous coal which are ever submitted to the process of coking; in anthracitic coal there is not a sufficient quantity of gaseous matter present to render the process of coking necessary or practicable.

The means employed for coking bituminous coal depend upon whether the coal to be coked is of a caking or non-caking quality. For coking the caking coal, ovens are almost always used. From two to four tons are usually coked at each operation. In the best ovens the great objects aimed at are :—first, as high a temperature as possible, by heating the air required for the combustion of the gases, previous to its admission into the oven; secondly, the utilisation of the heat produced, by carrying the ignited gases under and round the oven before allowing them to pass off; and thirdly, the admission of the smallest quantity of air necessary for combustion, at such a point in the oven as will best prevent any cutting or wasting action upon the coal, either during the process of coking or afterwards, before the charge is drawn.

In South Staffordshire and elsewhere, where the coal is of a non-caking quality, open coke fires only have hitherto been used. These consist in their simplest form of a brick chimney or open flue, about 4½ to 5 feet high, and about 2 feet diameter inside at the base and 18 inches at the top; around which the coal to be coked is carefully arranged, air holes being left in the sides of the chimney. The largest and longest pieces of coal are first piled up against the central chimney; against and upon these, other large coals are piled until they reach up as high as the chimney itself; and outside these again other coals of

smaller size, the outside of the coke heap being carefully rounded off with smaller coal or cobbles. The quantity of coal coked in open circular coke heaps varies from 10 to 30 tons, according to the quality of the coal and the purpose for which the coke is required. When the heap has been thoroughly rounded off, fine coke dust is mixed with water into a sort of paste called "blacking," and with this the whole of the heap is carefully covered, excepting about 6 inches height at the bottom, which is left open to admit the necessary amount of air for the combustion of the coal. Fire is then applied to the top of the coke heap close to the chimney; it gradually spreads along the line of draught down the chimney, and when it has attained sufficient strength it bursts out at the foot of the heap. As soon as this is the case, and the lowest portion of the heap is sufficiently coked, the bottom of the heap is gradually covered up with dry coke dust, so as to exclude the air and prevent the waste which would otherwise occur. As the fire extends upwards, the blacking gradually burns off higher and higher; and as this takes place, the fresh covering of dry coke dust is also extended upwards, but so as always to leave space enough between it and the unburnt portion of the blacking for allowing a sufficient quantity of air to enter to complete the coking process and avoid smothering the coal. When the blacking has burnt off entirely, the covering of new coke dust is made complete to prevent any further admission of air; the whole is damped down and allowed to cool gradually, and water is then poured into the fire to complete the cooling, and to act to some extent as a desulphurising agent, aqueous vapour always acting more or less in that way when in contact with red-hot coke. The process is now complete and the coke is drawn for use. Besides the round coke heap with one main central chimney or flue, long heaps with one or more chimneys or flues are frequently used; but in every modification of size or shape the same general principles are invariably carried out. The air to support combustion always enters the fire from the surrounding atmosphere, and the products of combustion in the shape of dense masses of smoke or flame pass off from the chimneys; there is also always a greater or less extent of surface of burning coal exposed to the air. In fact no one of the various processes connected with the manufacture of iron has so great an effect in destroying the

general appearance of an iron-making district and filling the atmosphere with smoke as the open coke hearths; and hitherto it has seemed as if it were precisely in this department of the manufacture that it is the least possible to get rid of this nuisance.

In consequence of having largely employed the pitch produced in the distillation of coal tar for the purpose of giving a binding or caking property to the non-caking small coal or slack of the South Staffordshire district, the writer's attention was directed to the possibility of collecting the products of combustion from the open coke heaps. It is well known that all bituminous coals give off in combustion gaseous products which yield by condensation certain quantities of gas tar and ammoniacal liquor. The quantities of both vary greatly according to the character of the coals themselves, the more or less perfect condensation of the gases, and the temperature at which the coking process is effected. As a general rule Cannel coals yield the largest percentage; and with all coals, the lower the temperature during the distilling or coking process, the greater is the quantity of gas tar obtained. A few simple experiments showed the possibility of collecting some of these products from the open coke heaps. A pipe was inserted into the coke heap near the top of the central flue, and its other end brought down into a bucket filled with water. A portion of the products of combustion was at once condensed, and ammoniacal liquor and some small quantity of gas tar were obtained. This experiment was followed by more careful ones, which led at last to the process of Open Coking now to be described.

The new arrangement is shown in elevation and plan in Figs. 1 and 2, Plate 38. A central chimney or flue A is built precisely in the ordinary way for coke heaps. From the bottom of the chimney a cast iron bend leads off into the pipe B laid about 2 feet below the surface of the ground, which delivers into the main C running at right angles to it and passing to the condensers D D; the condensers communicate at one side with the receiver E, and at the other with the stack F. Two dampers are provided for each coke heap, one to close the top of the chimney and the other to close the bend pipe at the bottom. The coals are arranged round the central chimney exactly as in the ordinary

coke heaps, and the heap when rounded off on the outside is covered with the ordinary blacking. This blacking however is spread over the entire heap and no open margin left for draught at the bottom, as is generally the case in the open coke heaps. Fire is now set to the heap at the top: the top of the chimney is closed by its damper, thus shutting off all direct communication between the open air and the chimney; and the damper closing the bend pipe is lifted up, so as to open a free passage into the pipe B. If the stack F connected with the condensers be powerful enough, sufficient air for the combustion of the coal passes through the coating of blacking to the fire; and as combustion goes on in the heap, the gaseous products given off pass into the central chimney and thence along the pipe B and main C to the condensers D. The main C is laid with a slight fall towards the condensers D, and is kept cool by a current of water G passing over its entire surface; and the condensers D are also cooled by jets of water H allowed to flow over them.

As soon as the fire is at all advanced, gas tar and ammoniacal liquor begin to flow from the lower end of the main C into the receiver E. The gases after leaving the main pass into the first large condenser D and thence into the second, in both of which condensation goes on; and finally the uncondensed portions of gas pass off into the stack F. From both the condensers D ammoniacal liquor and gas tar are collected and flow into the receiver E. Condensation in these condensers is facilitated by a series of iron plates placed in them, against which the uncondensed gases strike as they pass onwards towards the stack F. These means of condensation are very imperfect and are capable of great improvement, but were adopted as being at the time the most convenient. If the draught of the stack F be sufficiently powerful, and if the pipes B and main C are of sufficient area, combustion goes on somewhat more rapidly than in the ordinary coke fire. No smoke properly so called is ever visible, except from the top of the stack F. No open burning surface is ever allowed to exist, and consequently even at night no flame whatever is visible; the blacking never burns off entirely, but as it dries and becomes partially consumed on its under surface where resting upon the hot coke it is renewed from time to time, thus preventing any unnecessary waste in the coke heap, and consequently

the yield of coke is larger than in the ordinary method of open coking. No greater care is required in attending to the fires than in the ordinary coking, and thus no extra expense is incurred.

In the arrangement of the pipes and main three points require attention. First, the area of the pipes and main must be sufficient for the free passage of the products of combustion. The pipes B hitherto employed, as shown in Plate 38, are 12 inches diameter from the chimney to the main, and the main C itself is 18 inches diameter; but the first should be at least 15 inches and the latter 24 inches diameter. Second, the amount of fall both in the pipes B leading into the main and also in the main C itself must be sufficient to carry off the condensed products as rapidly as they are formed. If this be not the case, the result is that, the gases being partially condensed the moment they leave the chimney of the coke heap, gas tar is produced, which, if it does not pass off at once, is again distilled by the great heat of the pipe B where it passes underneath the coke fire, and solid pitch is produced, which gradually accumulates and chokes up the pipe. It is therefore desirable to have manholes or lids I to these pipes, so that they may be examined and cleared out from time to time. Third, the cooling of the main C by a stream of water flowing over it. To effect this the main is laid in an open brick culvert which is kept filled with a current of water G. It is desirable to have manholes on the main also, so as to be able to examine it at any time; but if properly cooled by water, and laid with sufficient fall, it will keep clear without any attention. The water reduces the temperature below that at which re-distillation of the liquid products of condensation can take place, and consequently no solid products can be formed to block up the main itself; but this depends altogether upon the main being kept properly cooled.

The quantity of liquid products obtainable by the condensation of the gaseous products of coking is very remarkable. It is known that in the process of coking in closed retorts the gaseous products given off produce on an average, by their partial condensation alone, 20 gallons of gas tar and ammoniacal liquor per ton of coal; and by the imperfect method of condensation from open coke fires, as now described, even a

larger quantity of liquid products is obtained. Every ton of coal coked in this manner yields from 30 to 40 gallons of ammoniacal liquor and gas tar: so that in works where 100 tons of coal per day are coked, at least 3000 to 4000 gallons are given off into the atmosphere daily in the shape of smoke and invisible vapour. How important must be the chemical changes which are constantly being produced in the atmosphere by the great manufacturing processes, but of the extent of which, in consequence of their being invisible, we are under ordinary circumstances utterly unaware. The results obtained and the chemical changes produced in a visible form by the new method of coking illustrate this remarkably: a continuous stream of liquid matter runs into the receiver, which but for this simple arrangement would have been all thrown away into the atmosphere. The excess of products condensed in this mode of coking, in comparison with those obtained by the condensation of gas made by distilling coal in closed retorts, is easily explained. In the open coking, the coal is in wet weather saturated with moisture; the blacking used must of necessity be so; and in watering the fires, although the damper is closed at the bottom of the chimney, yet no doubt some aqueous vapour will pass by it into the main. But probably the greatest source of this excess is to be found in the water actually produced by the combustion of the hydrogen of the coal and the oxygen of the atmosphere.

In reference to the value of the products obtained, ammoniacal liquor and gas tar, the first is of course, from the excess of aqueous vapour just alluded to, weaker than the ammoniacal liquor of gas works: 750 gallons of the liquor saturate 72 lbs. of sulphuric acid and produce 112 lbs. of sulphate of ammonia, a quantity which though small in itself is yet sufficient to be worth extracting commercially. The value of the second product, gas tar, has not as yet been fully ascertained: the analyses made of it however show that its constituents are very different from those of ordinary gas tar and apparently more valuable. It does not contain so much naptha, but a much larger quantity of the light photogenic oils now so extensively consumed in lamps, and a large quantity of paraffine.

The great variety of hydro-carbon products existing in gas tar, and their great and daily increasing value owing to the numerous purposes

to which they are now being applied, render any new means of obtaining them upon a large scale a subject of much interest. From them are now obtained naptha, creosote, photogenic oils of light specific gravity admirably adapted for consumption in lamps, heavier oils for lubricating purposes, and paraffine which is used as a substitute for wax in the manufacture of the best candles. Besides these, benzole and other compounds have recently been obtained, and are now employed largely in the production of the beautiful colours mauve and magenta, which have been so much used in dyeing during the last two or three years. So rapidly have the purposes to which these hydro-carbon products are applied been extended, that pitch, which was previously considered worthless for chemical purposes and had accumulated at chemical works as refuse waste, has during the last two years become so much in demand that it was its advancing price and the increasing difficulty of obtaining it that led to the experiments for collecting the products of combustion from open coke fires. The results show how boundless are nature's resources, when science discloses the means of utilising them. In the smoke which pollutes the atmosphere and destroys the beauty of the district large stores of valuable matter are being wasted, which science shows may be employed not merely for the ordinary purposes of daily life but also for those of decoration and ornament. Surely the time will come when science and manufactures will be brought into such close alliance with each other that all that is now distasteful and unsightly in manufacturing processes, which is almost always connected with waste, shall disappear.

Mr. J. E. Clift fully agreed in the importance of preventing waste of the products of distillation in coking coal, which had hitherto all been lost in the ordinary coking heaps; but he did not see how this object could be secured by an open fire, such as that described in the paper appeared to him to be, and thought it could not be effectually done except by coking the coal in closed retorts, as in the manufacture of gas. In coking coal in an open fire the combustion was carried on by

means of the gases given off from the coal, and so much of these gases as was consumed could not be condensed and utilised; and it appeared to him that the condensible products obtained from any open fire must be small in quantity, the greater portion of the gases being inevitably lost by their combustion. By the use of closed retorts or ovens the desired economy might undoubtedly be effected, and would prove of great value to ironmasters making large quantities of coke.

The proportion of distilled products to be obtained from different coals varied considerably, some coal yielding only 6 gallons of tar and 30 of ammoniacal liquor per ton, while 16 gallons of tar and only 8 of ammoniacal liquor per ton were got from others. There was also a great variety in the quality of these products. The ammoniacal liquor distilled from North of England coal yielded both muriate of ammonia and carbonate of ammonia; while that from South Staffordshire coal contained only carbonate of ammonia and a little sulphate. The tar also from different coals varied much in the quantity of naptha it contained, upon which its value depended. The plan of condensing by means of a stream of water was an expensive one, unless there were a natural supply of water at hand, since the cost of pumping would be great when the process was carried out on a large scale, and might exceed the value of the products obtained: he thought it would be better to expose a large surface to the atmosphere instead of to water, as was generally the plan in gas works, where a large extent of upright pipes was exposed to the atmosphere, through which the gas was passed on its way to the receiver. Some ovens on Lord Dundonald's plan had been erected near Tipton at the end of the last century, for obtaining tar by distillation from coal, but they were abandoned because the manufacture of tar by that means was not profitable; but the value of the gas and coke was not then understood, and it was a curious circumstance that, though there was much similarity to the present manufacture of gas, it was even considered an inconvenience that gas was produced from the coal when tar only was wanted.

Mr. E. A. Cowper did not agree in regarding the process described in the paper as entirely dissimilar to that of coking in a closed oven or retort, and thought that tar would be produced in the

former mode just as in the latter, though there might be a difference in its quality. The fire in one portion of the coal in the heap distilled the tar from the adjoining coal, and the distillation continued as the fire progressed through the heap; a certain proportion of the coal being of course consumed in the process, just as in a retort the coal inside was distilled by the consumption of other coal outside the retort. For condensing the gaseous products into a liquid form, an air condenser was certainly preferable where there was no natural supply of water; but its efficiency was greatly increased if the external surface was kept always wet by a thin film of water trickling down constantly over it, the evaporation of which carried off the heat much more quickly, producing rapid condensation within the vessel. He had used this surface-evaporative condenser for some time for a steam engine, and found it a very effective plan.

Mr. W. Mathews thought they were much indebted to Mr. Blackwell for the able manner in which he had taken up the subject, and the perseverance with which he had carried out the practical application of the plan. They had previously had under consideration the subject of the waste of coal now taking place in working the seam of Thick coal, and the necessity of using every expedient to economise what was left of it; and the new mode of coking afforded the means of saving a valuable element in the coal after being raised, which had hitherto been all thrown away. The plan appeared to him perfectly feasible for getting the products of distillation in making the coke; for the new coke heaps could not be considered as open fires, because they were completely closed with the layer of blacking, and the draught was reversed, the air entering all over the surface, and the distilled products being collected and drawn off at the centre, so that the heap assimilated in character to an ordinary closed oven. The essential point to be established regarding the value of the process was whether or not the coke so made was deteriorated in quality, so as to be unfit for the blast furnaces. If this were the case, either more coke would have to be used in the furnace or inferior iron would be made; which might outweigh the advantage otherwise obtained. The commercial value of the materials got by distillation had also still to be ascertained. The principle itself was one which if worked out to a successful issue

would be of great importance and advantage to the South Staffordshire district, where the quantity of small coal was so vast.

Mr. Blackwell remarked that, although this plan of open coking was a new one, it was in effect carrying out what had hitherto been done only in closed ovens; and the heap was really no longer an open fire, for the covering of blacking cased it completely on the outside and effected the same result as the brickwork enclosing ordinary coke ovens. The principle consisted in reversing the direction of the air through the heap, the air passing through the blacking all round in only just sufficient quantity to maintain a slow combustion; the admission of air was regulated as desired by loosening or removing any part of the blacking. If the chimney giving the draught were high enough to draw off the products of distillation as fast as they were set free, and prevent their becoming deposited in the coke, he thought the quality of coke obtained would be better than that from the ordinary heaps; in some cases the coke had already been found to be improved, besides a greater proportion being obtained from the coal, amounting to about $\frac{1}{2}$ cwt. more per ton of coal. In the first trials of the plan, the draught was imperfect, and not so good a quality of coke was made; but now the flues have been made larger and the stack raised, and since then the heaps when opened showed the best coke fires he had ever seen. The new mode of coking had now been in operation for three or four months, proving thoroughly successful as to the quality of coke made; if it proved as successful in respect to the various products obtained in the distillation, it would no doubt produce great changes before long in the manufacture of those materials. The quantity of tar obtained was not large, but several tons of oil and paraffine had been distilled from that already got; the materials had not yet been tested as to their commercial value, but tried only on a small scale by way of experiment. He understood the tar produced contained constituents of much greater value than any yet obtained, both for chemical and manufacturing purposes.

Some indirect advantages of importance had arisen in working out the new system of coking. So large a quantity of ammoniacal liquor had been made that there was more than could be used at present for the manufacture of other substances, and a great deal had therefore

been allowed to run away; this ran down through the cinder bank and drained into a pool of water from which the supply for the steam boilers and tuyeres was drawn. The water contained a great deal of carbonate and sulphate of lime, which caused much trouble by the scurf produced inside the boilers and tuyeres, the latter being constantly burnt off at the noses from the water spaces getting choked up: but after the ammoniacal liquor had run into the pool for a few weeks, it was found that all the scurf was removed, and all trouble of scaling and cleaning the boilers was saved, while the tuyeres were now never burnt. He was employing the ammoniacal liquor at his own works for mixing with the water to prevent deposit; and the tuyeres of five blast furnaces, 20 or 25 in number, using a great quantity of water, were all supplied with it.

Mr. J. E. Clift thought the plan was a valuable one for economising the waste slack and obtaining a useful description of coke from it; but with regard to the other products he did not think they could be got in sufficient quantity to be profitable by the system of open coking. He thought the amount of tar produced must be small, on account of the decomposition that would take place during the process; for the air entering the heap would decompose the light oils of the tar, and yield water instead of tar; while the pitch of the tar would be deposited on the hot coke, in passing through it towards the centre flue, so that there would be probably a large yield of coke, but very little tar condensed in the condenser; and this appeared indeed to be confirmed by the results at present obtained from the new coke heaps. By the use of closed ovens however almost the whole of the tar might be obtained, as well as all the ammoniacal liquor.

Mr. C. Cochrane asked whether any observations had been made as to the uncondensed gases escaping from the top of the chimney, and whether they might be used for heating purposes, like the waste gases from blast furnaces.

Mr. Blackwell replied that he had not been able at present to turn the uncondensed gases to any account; but he had erected an exhauster for drawing them off from the main pipe to examine them, and believed they would ultimately be found of value. The greater yield of coke obtained from the new heaps he did not consider

was to be attributed to a greater quantity of pitch being deposited in the coke, but to the fact that there was no burning of the coal to waste and no external flame as in ordinary coke hearths, so that even at night there was no surface combustion to be seen, but the heap was perfectly dark. He thought that ultimately all the products of the coal would be utilised, and was making experiments with that view; if the results were successful he would be happy to lay them before a future meeting.

The CHAIRMAN moved a vote of thanks to Mr. Blackwell for his paper, which was passed.

The following paper was then read :—

Fig. 1. *Front Elevation.*

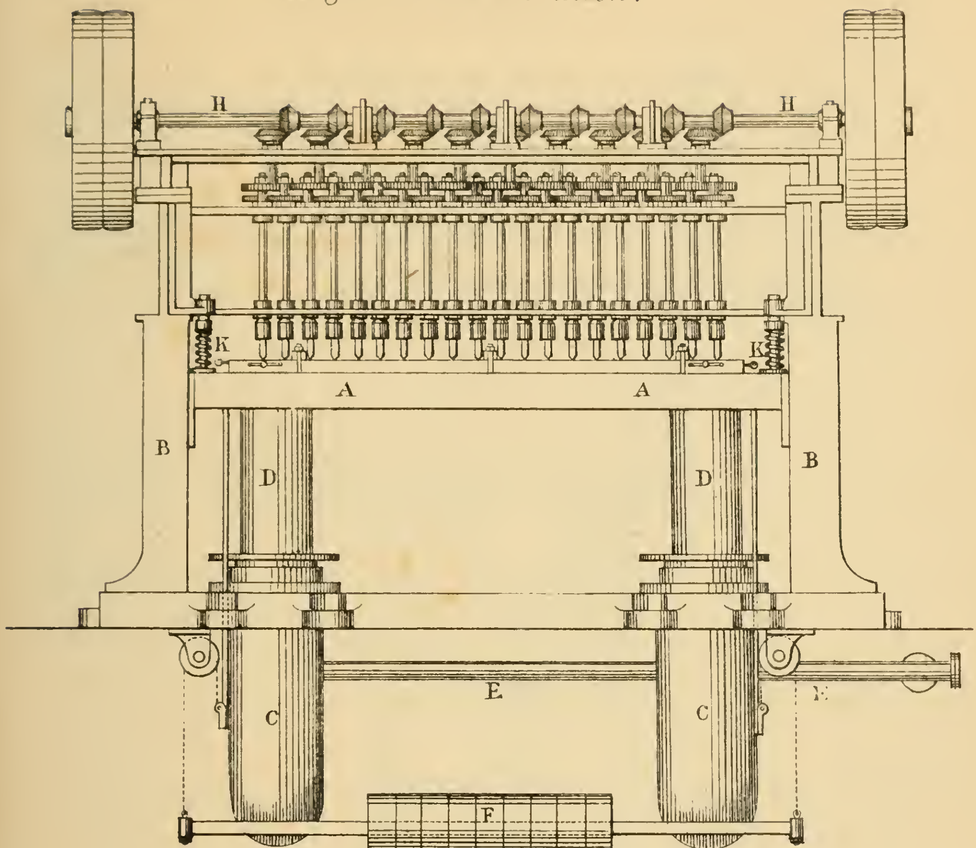
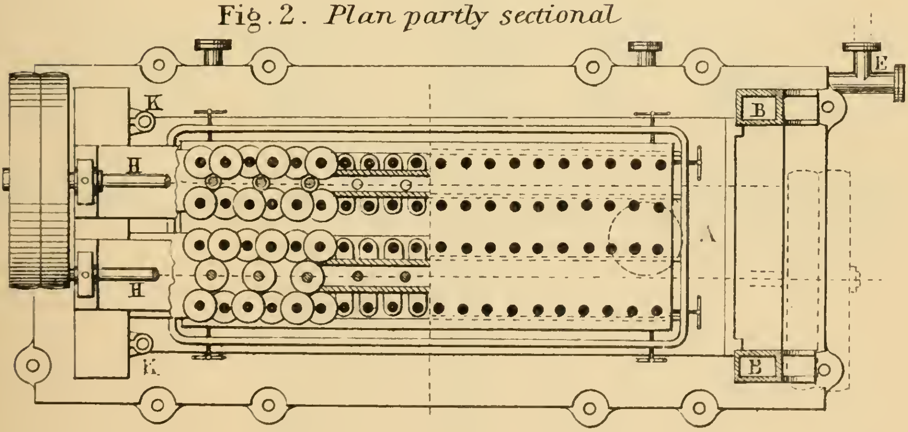


Fig. 2. *Plan partly sectional.*



Scale 1/40th

Fig. 3 *Longitudinal Section enlarged.*

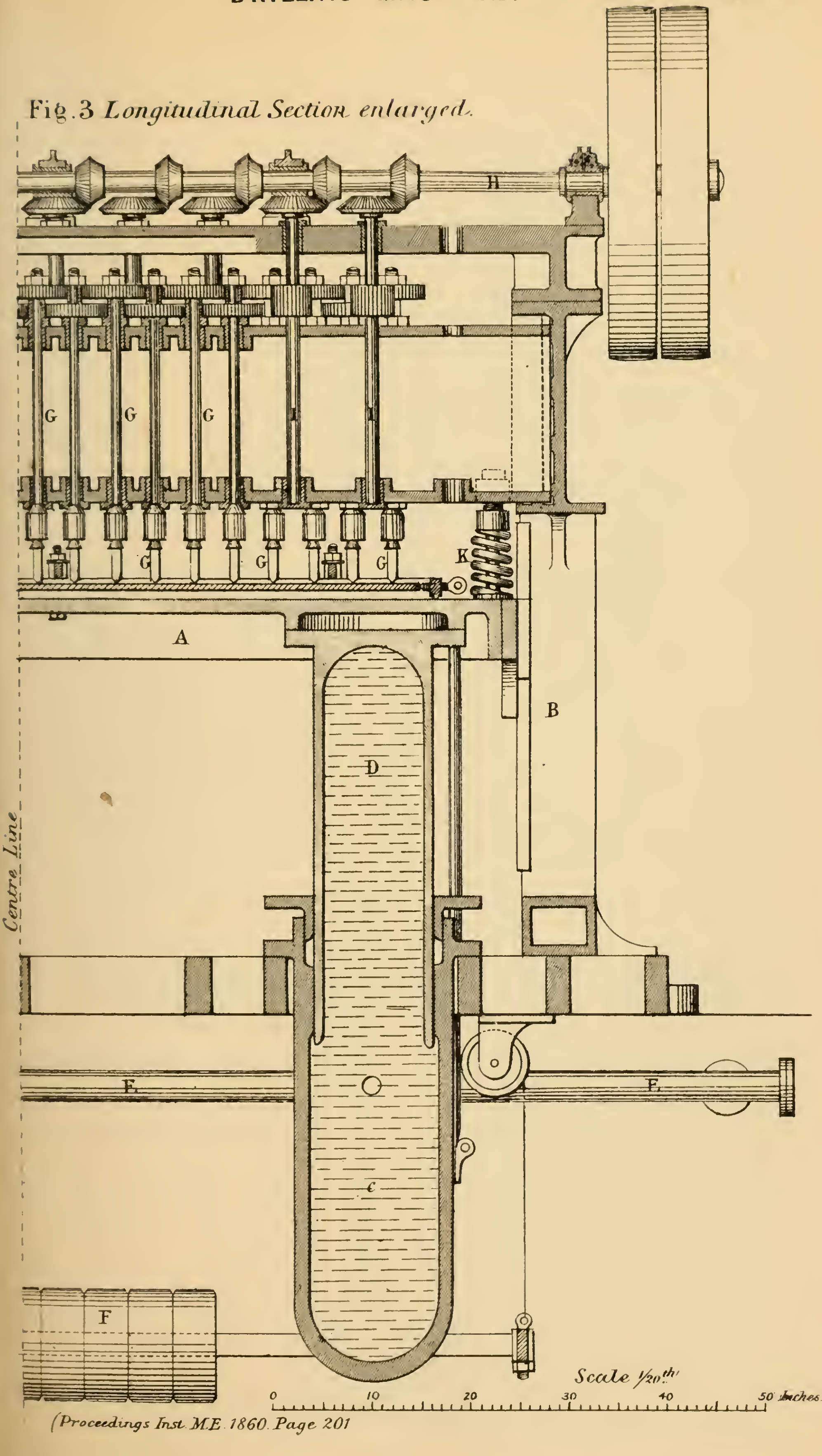
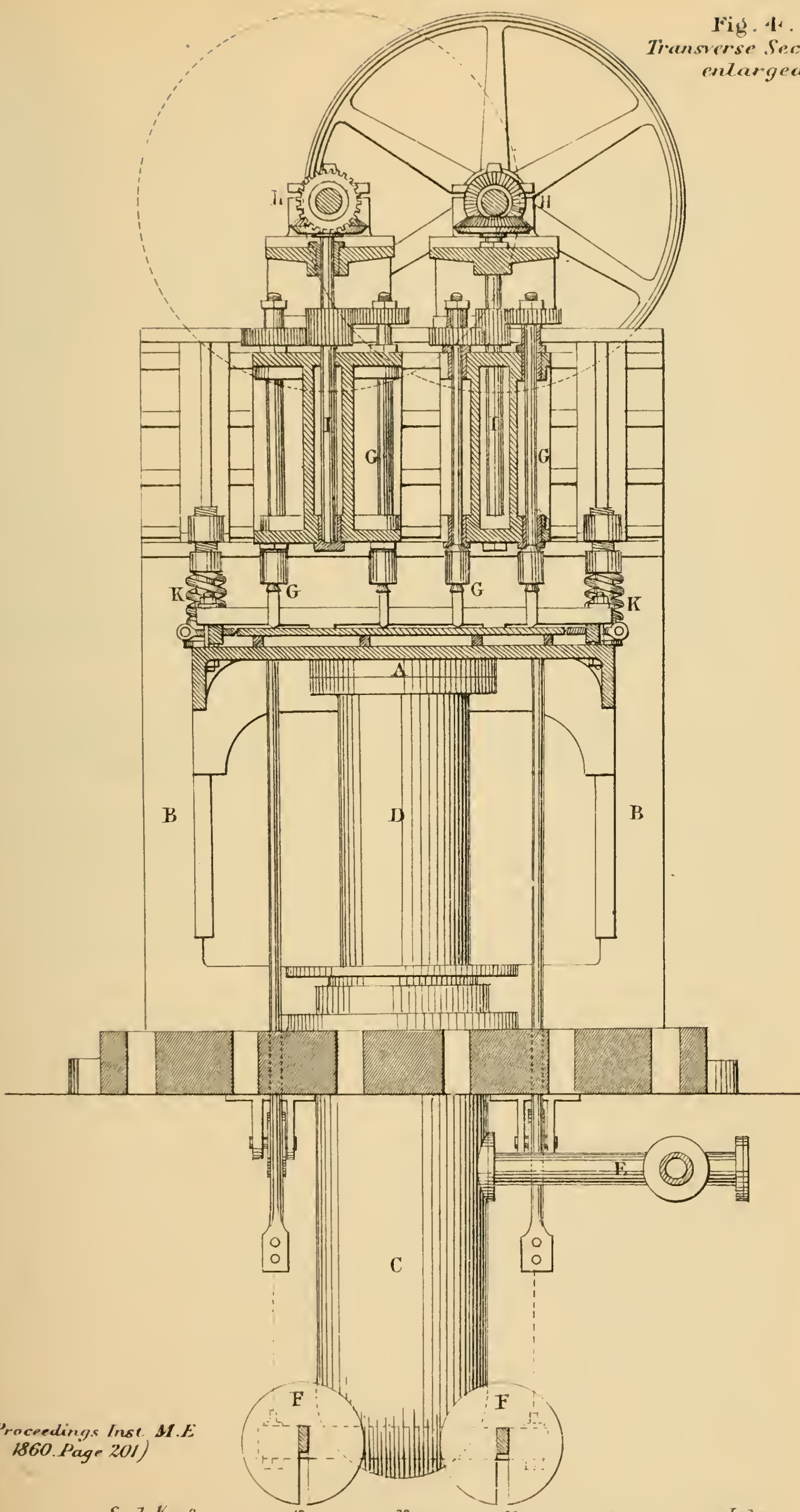


Fig. 4.
Transverse Section, enlarged.



(Proceedings Inst. M.E. 1860. Page 201)

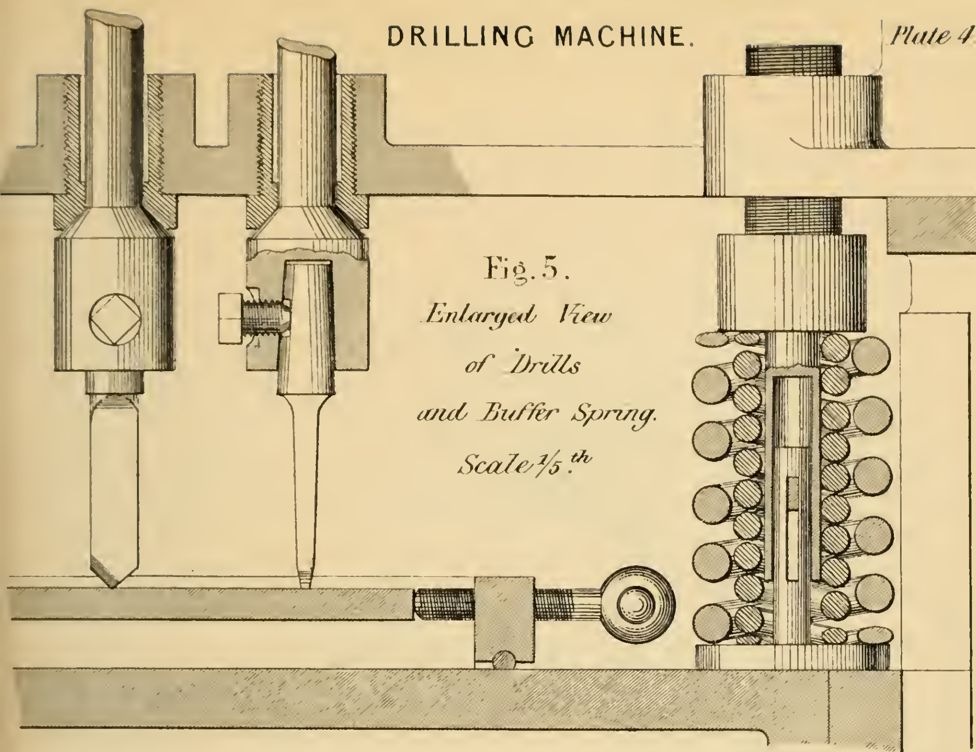
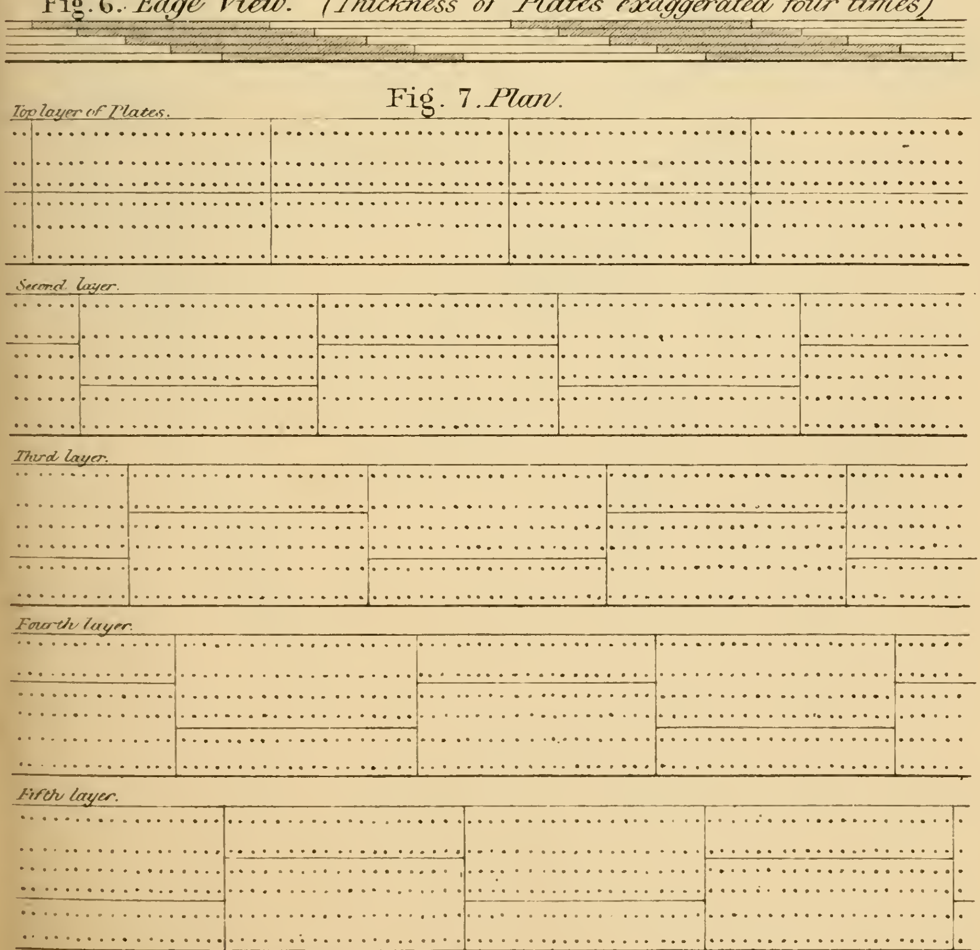


Fig. 5.
Enlarged View of Drills and Buffer Spring.
Scale 1/5th

Arrangement of Plates in Top Flange of Girder.

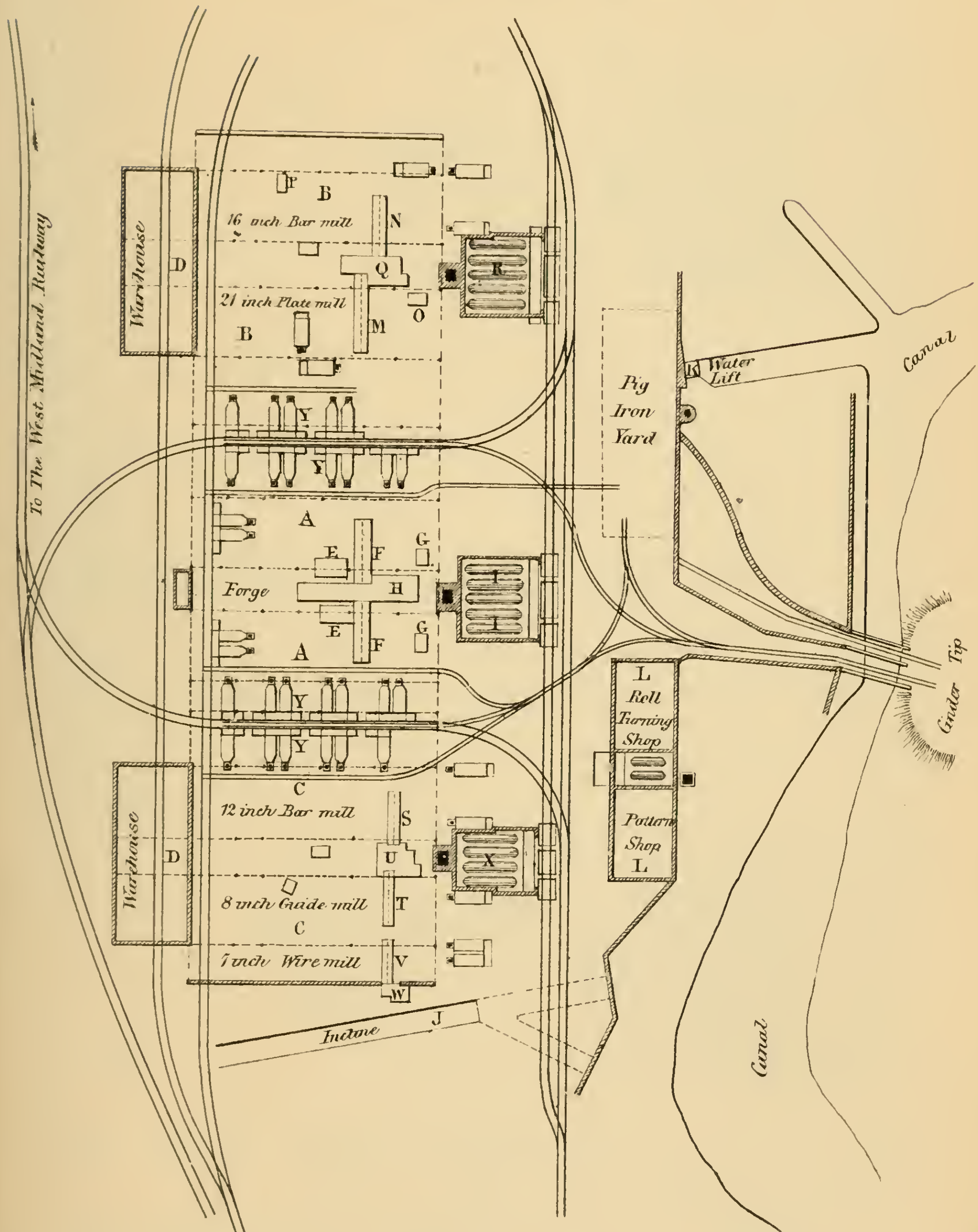
Fig. 6. *Edge View. (Thickness of Plates exaggerated four times)*

Fig. 7. *Plan.*



 Scale 1/80th

Fig. 1. *General Plan of Works.*

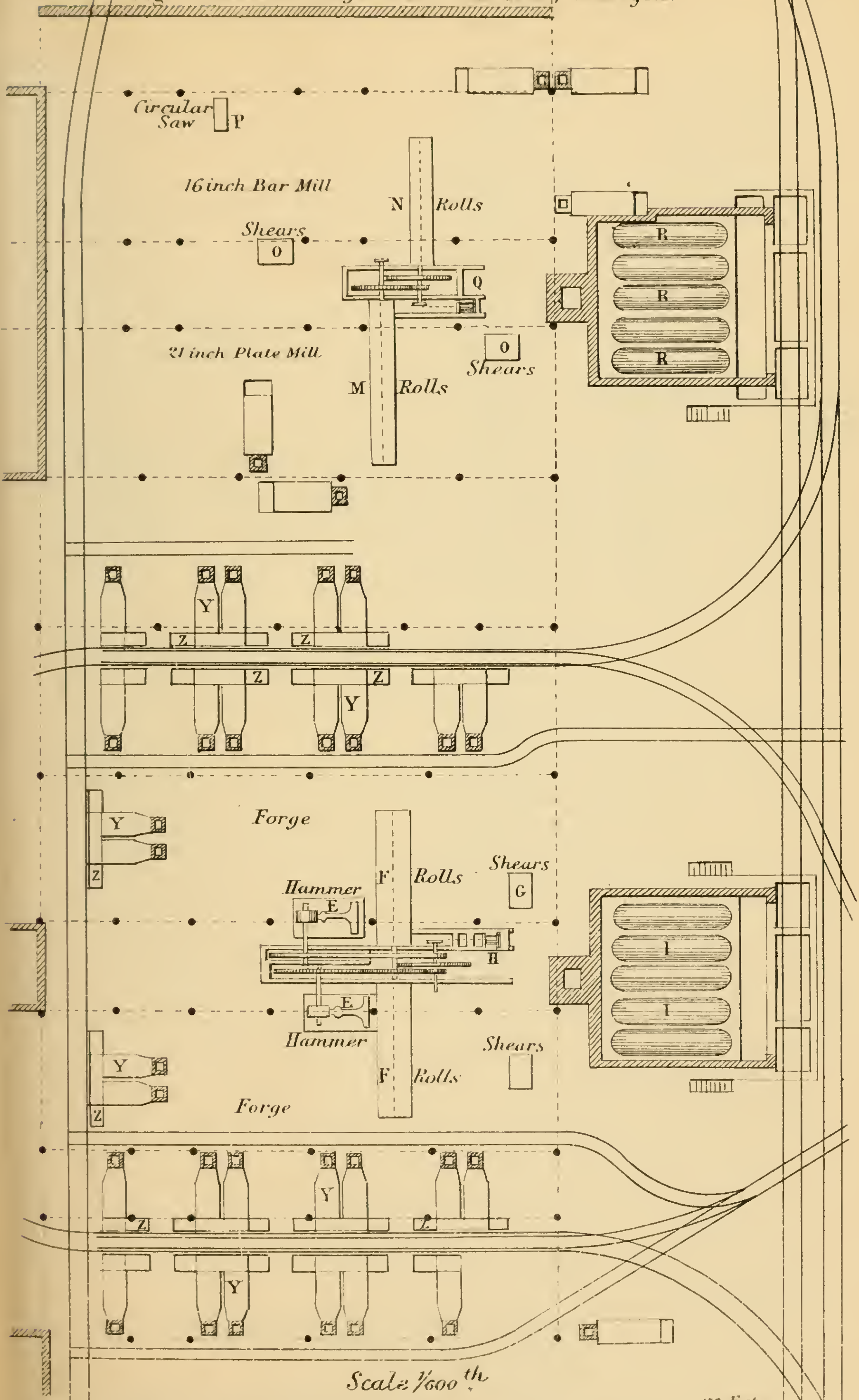


Scale 1/1500th

0 100 200 300 400 500 Feet.

(Proceedings Inst. M.E. 1860. Page 211.)

Fig. 2. Plan of Forge and Plate Mill, enlarged.



(Proceedings Inst. M.E. 1860 Page 211)

Fig. 3. *Plan of Forge Engine, Rolls, and Hammers.*

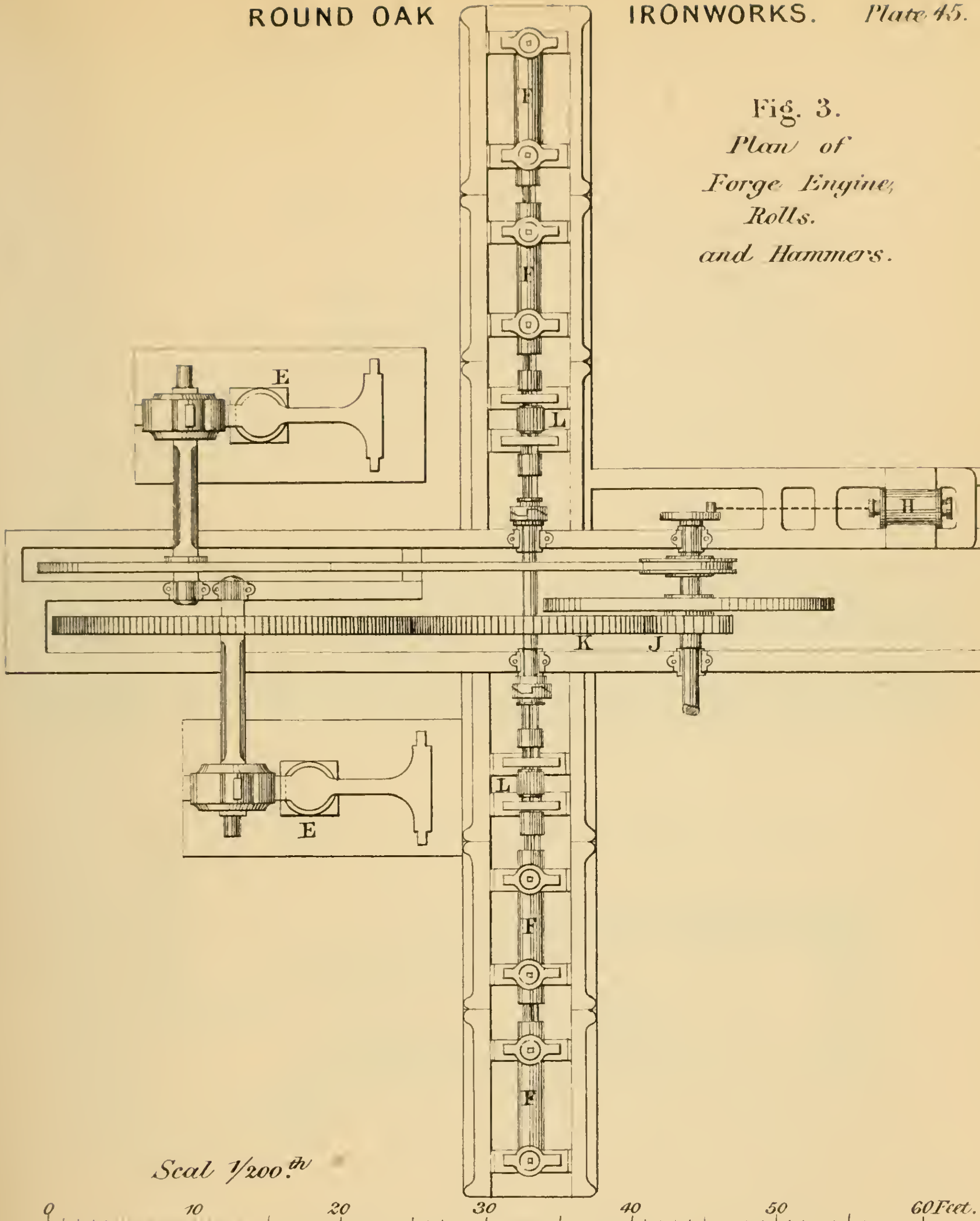
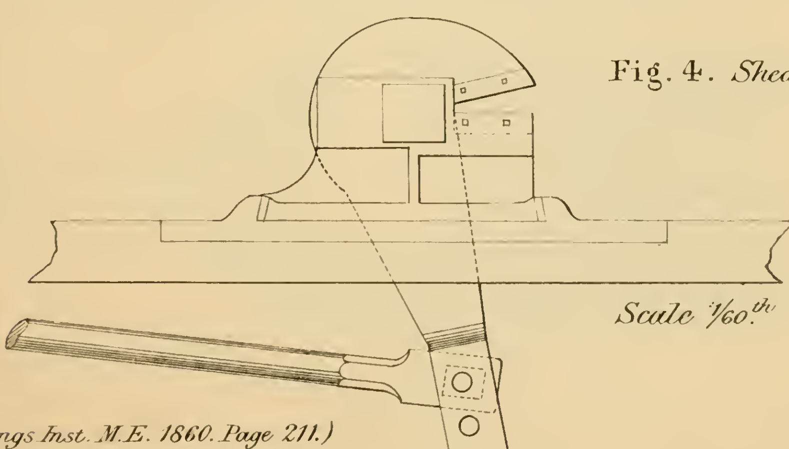


Fig. 4. *Shears.*



Scale 1/60th

Fig. 5. *Forge Hammer.*

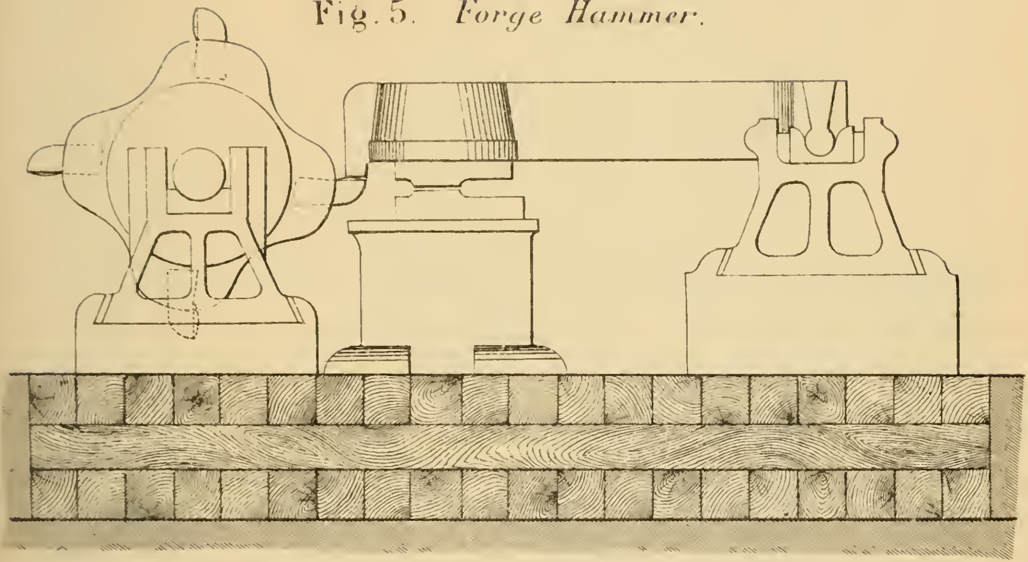


Fig. 6. *Puddling Furnace. Longitudinal Section*

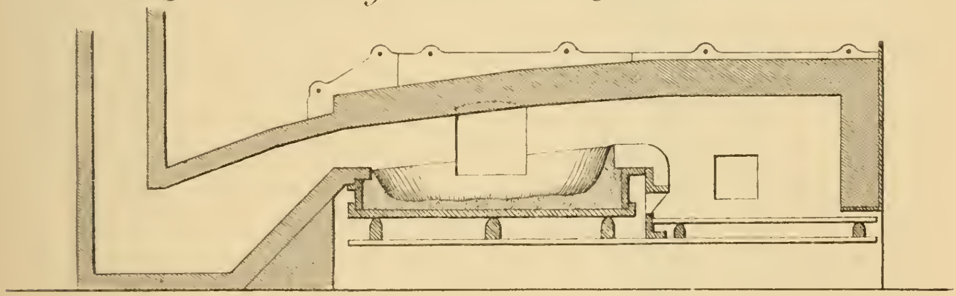
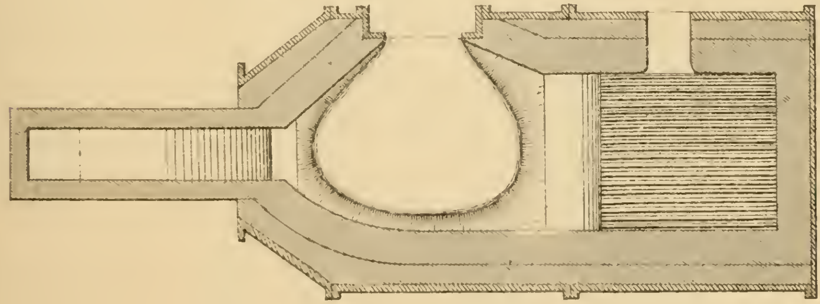


Fig. 7. *Sectional Plan.*



Scale 1/60th.

0 5 10 15 20 Feet

(Proceedings Inst. M.E. 1860 Page 211.)

DECIMAL MEASUREMENT.

Fig. 1. *Side Elevation of Measuring Machine, for measuring by End or Contact measurement.*

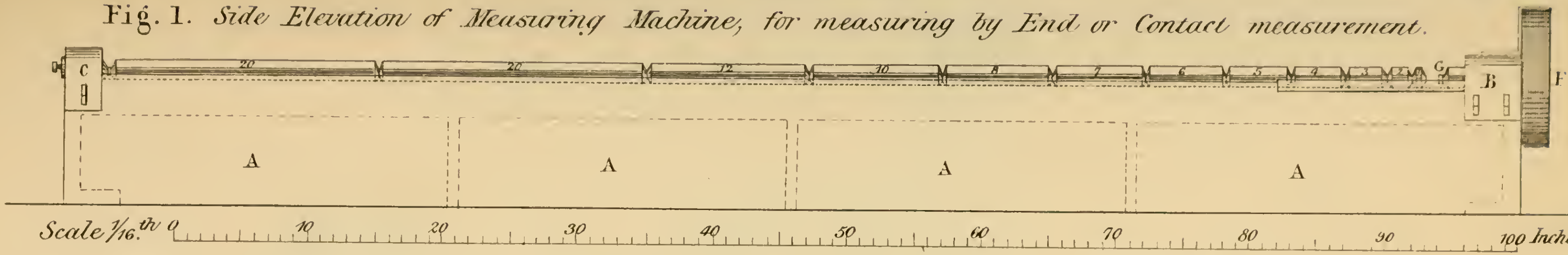


Fig. 2. *Plan, enlarged.*

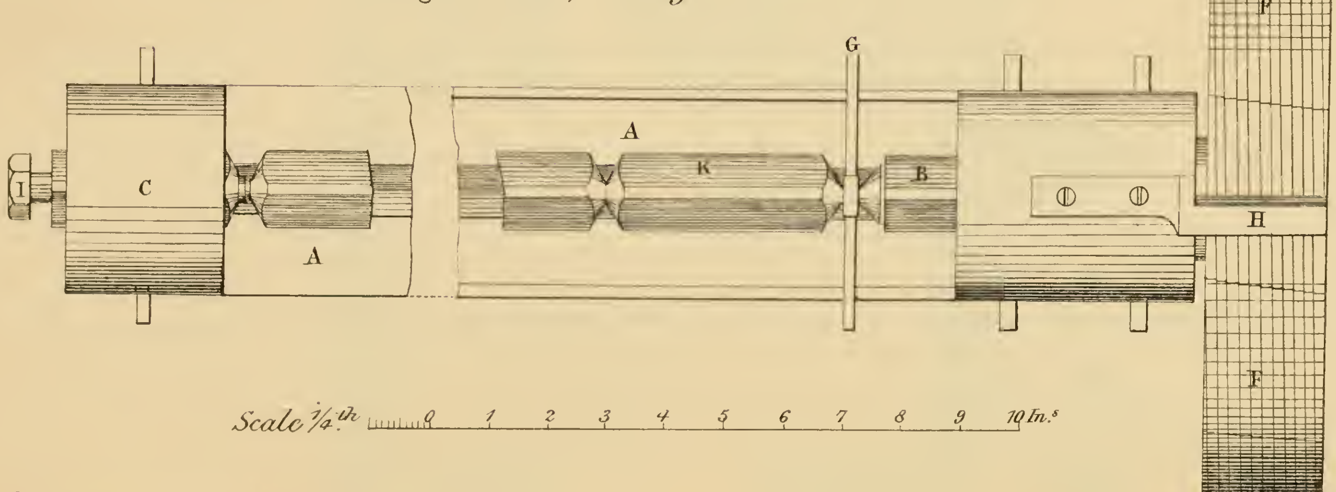
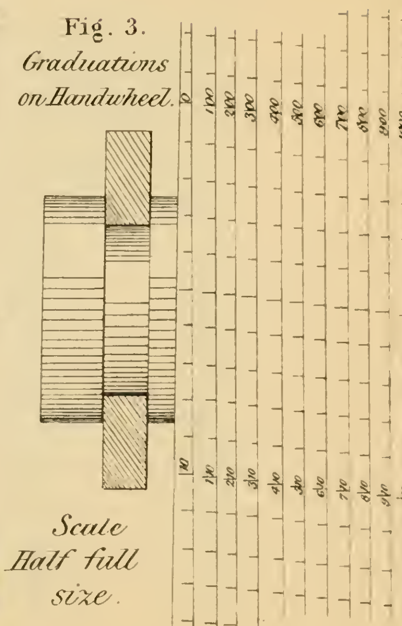


Fig. 3. *Graduations on Handwheel.*



Scale Half full size.

(Proceedings Inst. M. E. 1860, Page 223.)

Plate 47.

Fig. 4.
End Elevation of Back Centre.

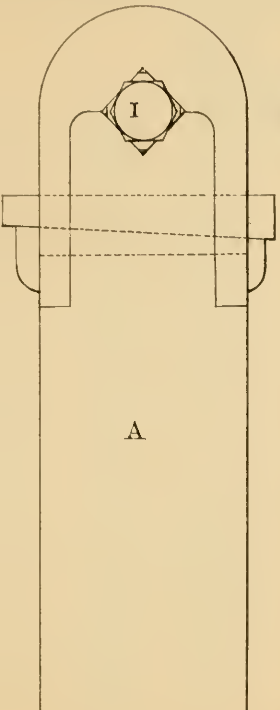


Fig. 5.
Longitudinal Section

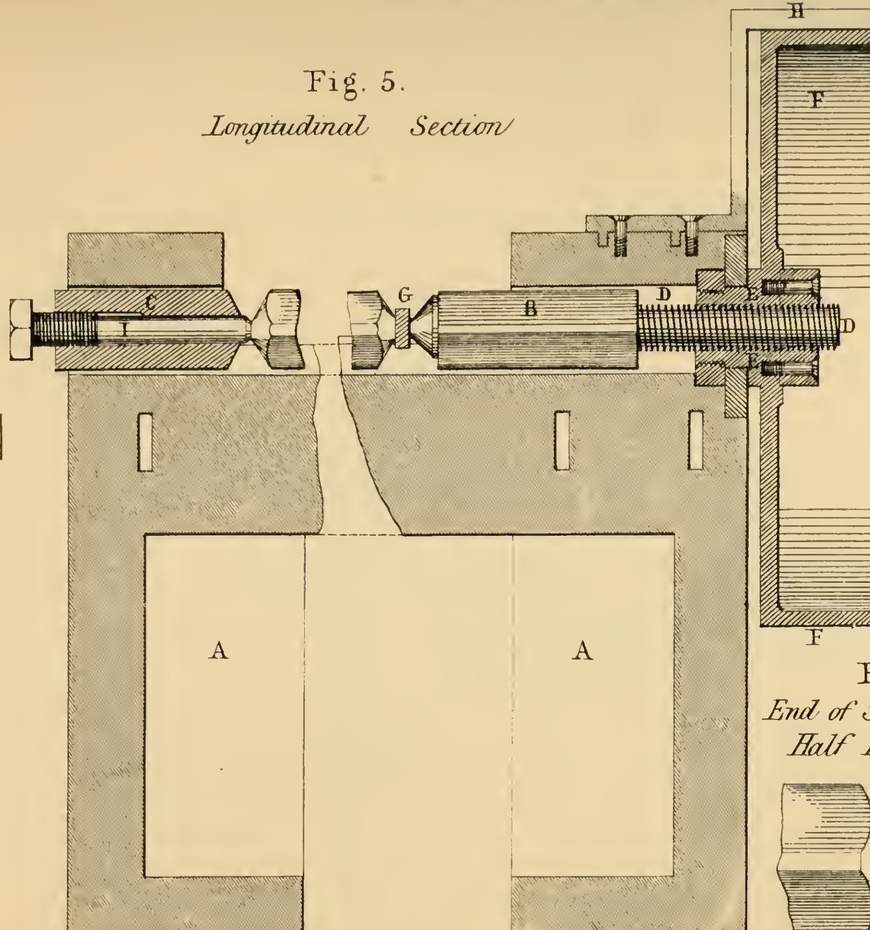


Fig. 6.
Transverse Section.

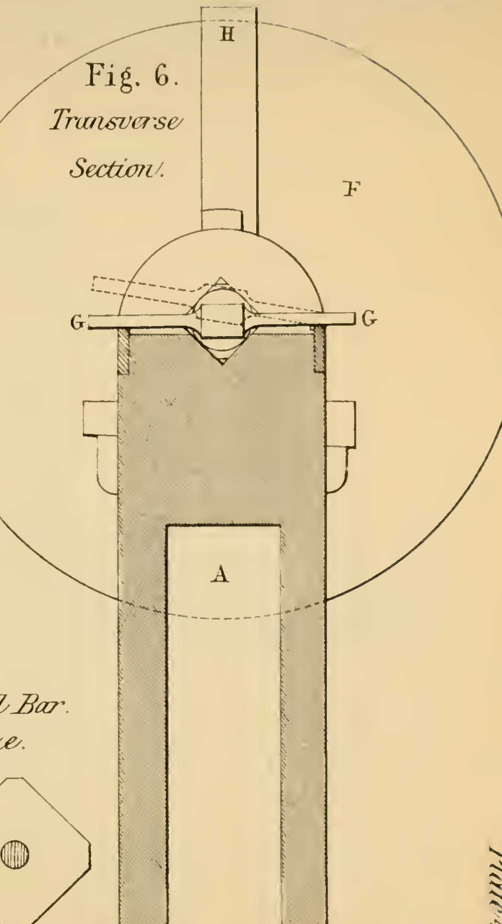
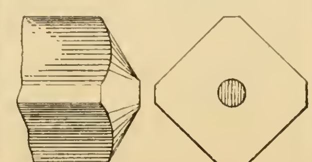


Fig. 7.
End of Standard Bar. Half Full Size.



Scale ¼th 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Ins

STONE-CRUSHING MACHINERY.

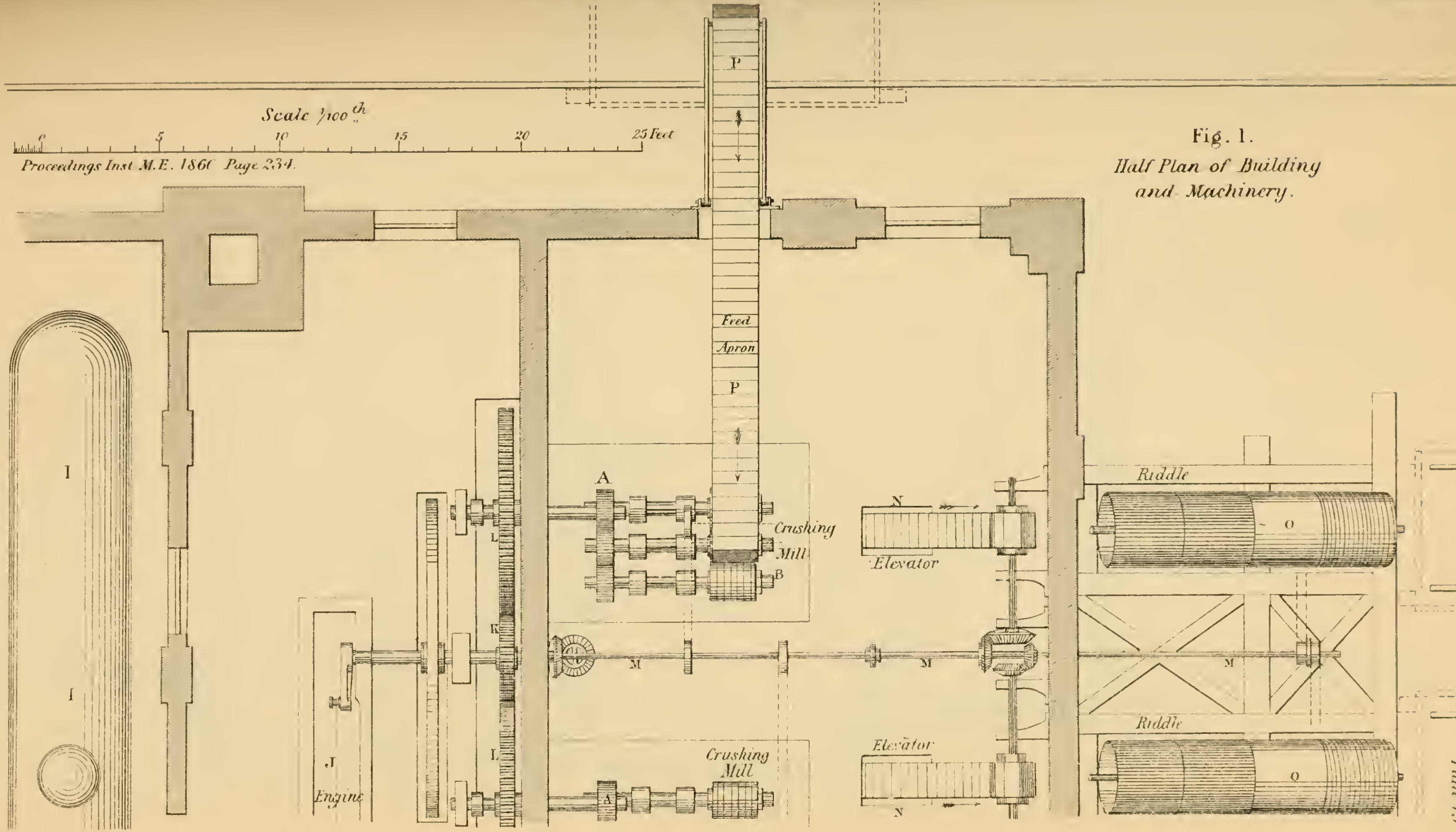


Fig. 1.
Half Plan of Building and Machinery.

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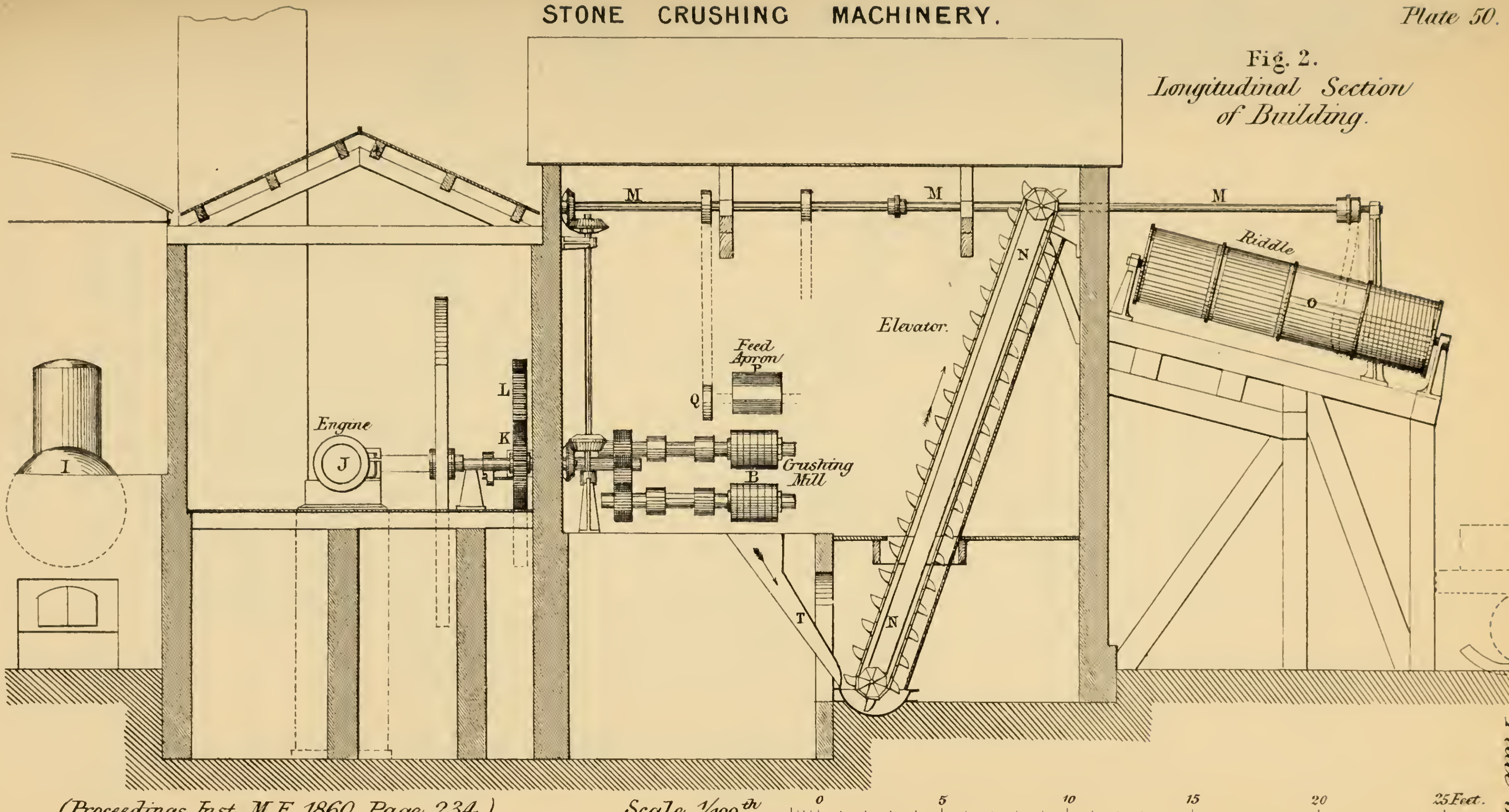
Plate 49

STONE CRUSHING MACHINERY.

Fig. 2.
Longitudinal Section of Building.



(Proceedings Inst. M.E. 1860. Page 234.)

Scale 1/100th

Fig. 3.
End Elevation of Crushing Mill, partly Section.

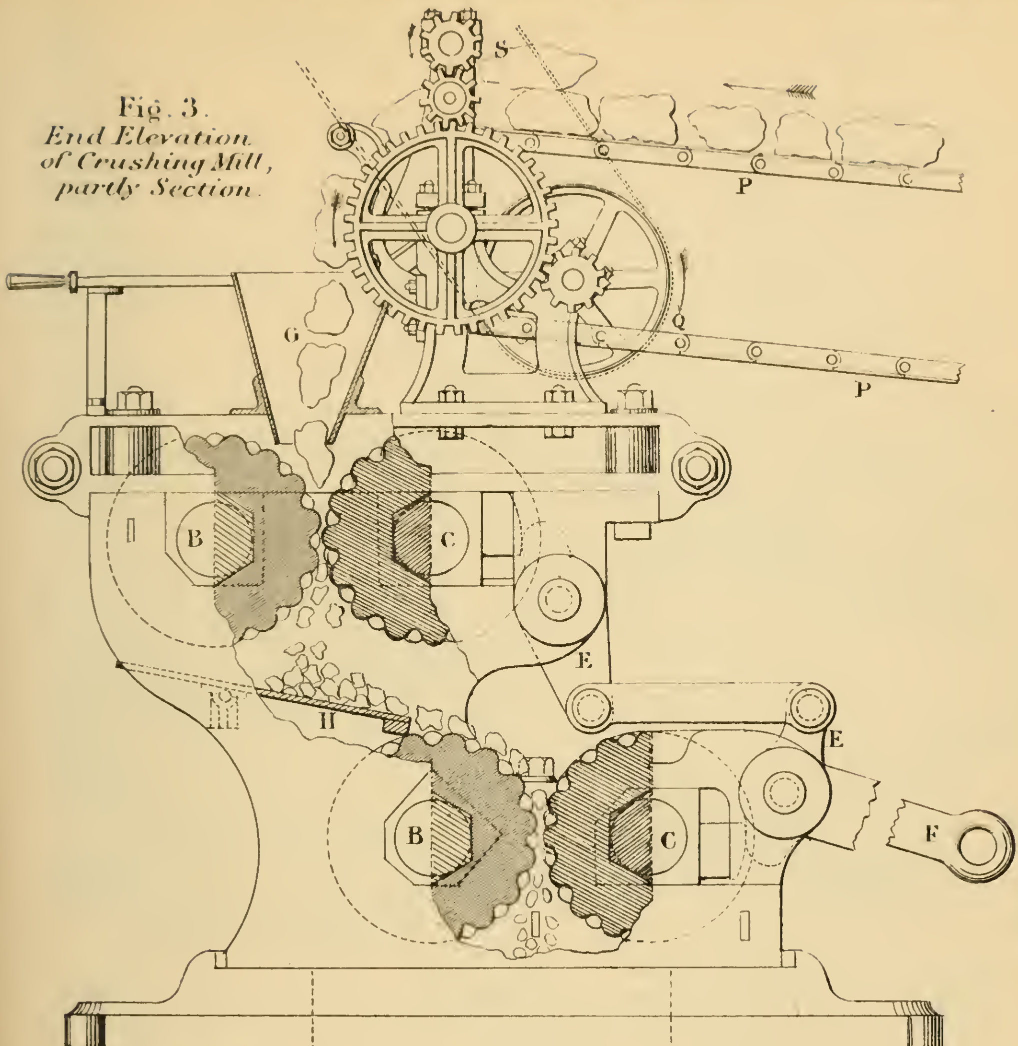
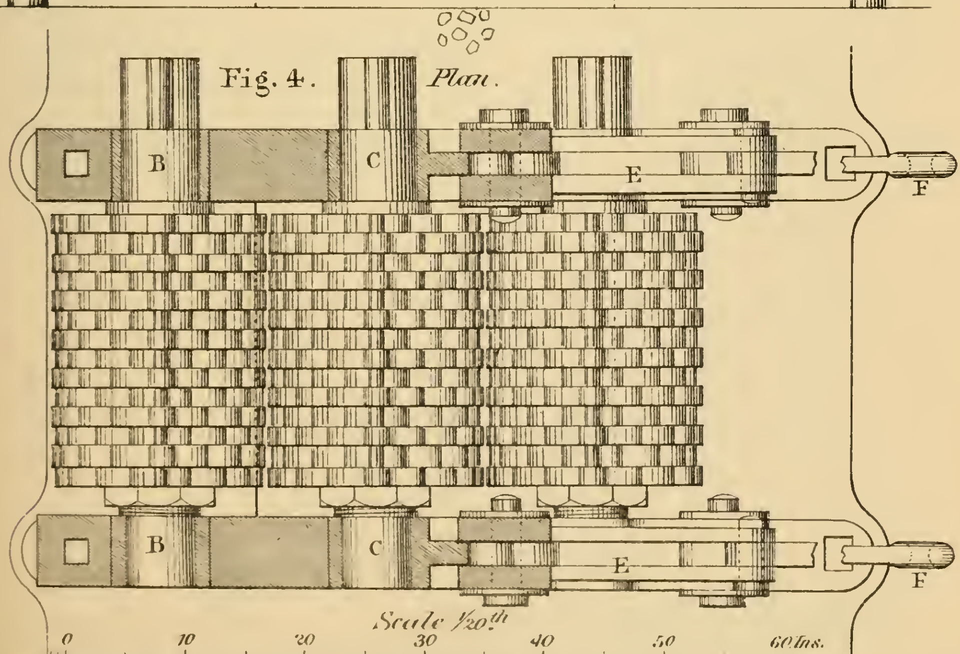


Fig. 4. *Plan.*



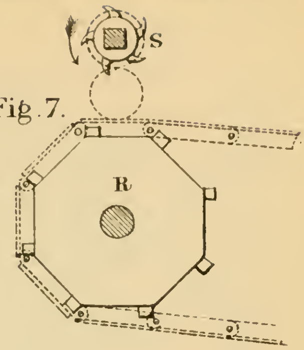
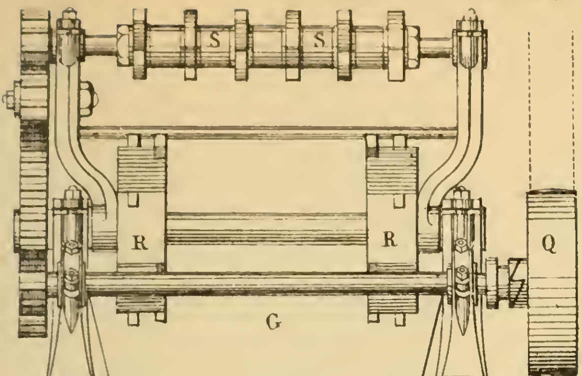


Fig. 7.



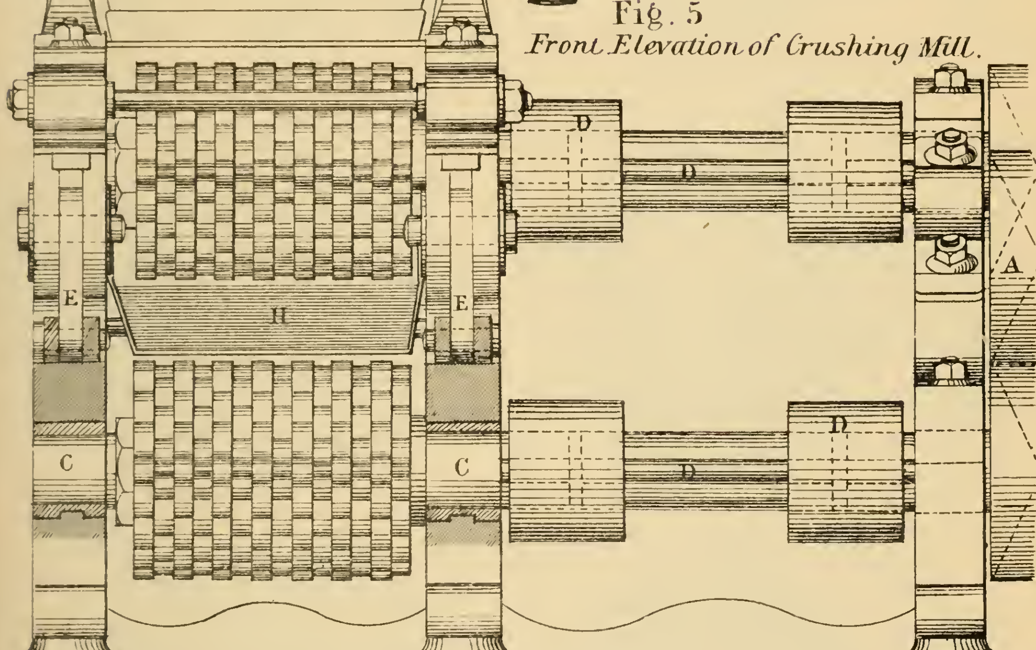


Fig. 5

Front Elevation of Crushing Mill.

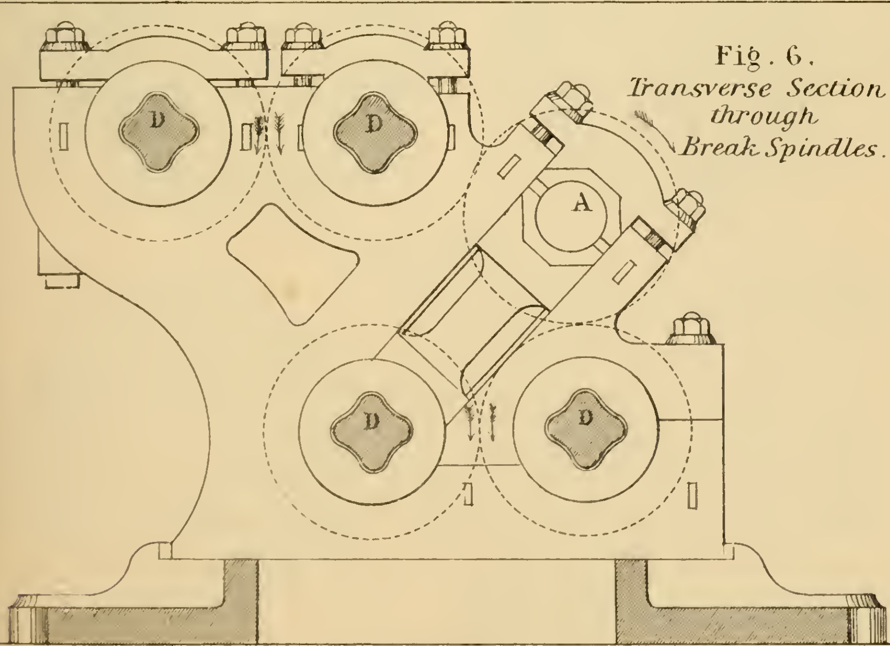


Fig. 6.

Transverse Section through Break Spindles.

Scale 1/20th 0 10 20 30 40 50 60 *Inches.*

Sections of Crushing Rolls.

Upper Rolls.

Fig. 8.

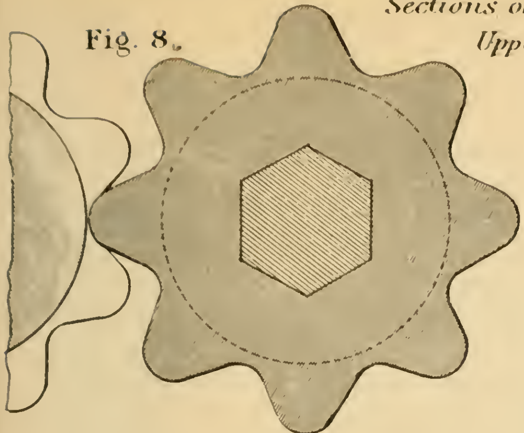
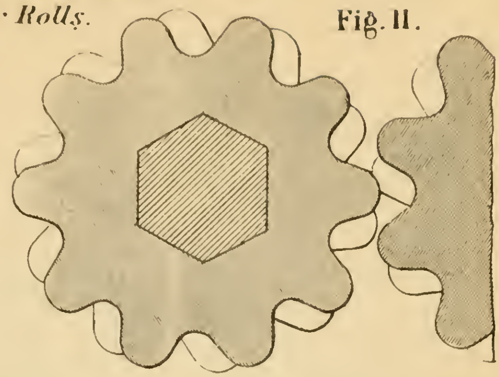


Fig. 11.



Lower Rolls

Fig. 9

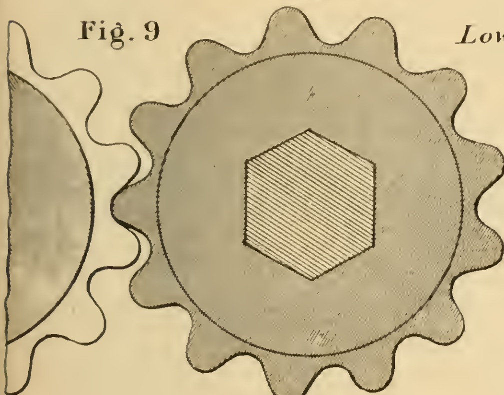
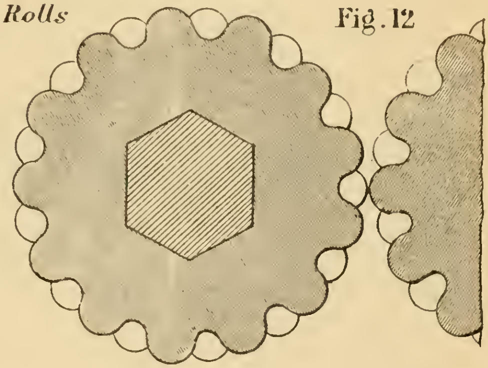


Fig. 12



Lower Rolls

Fig. 10.

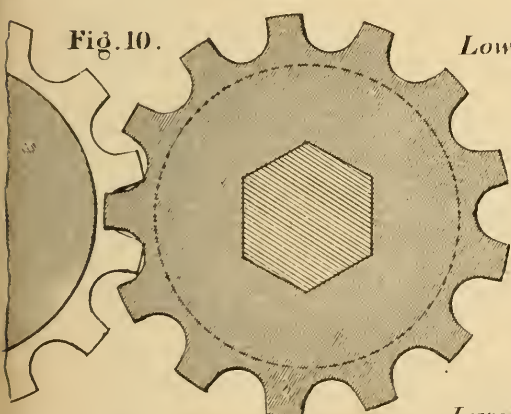


Fig. 13.

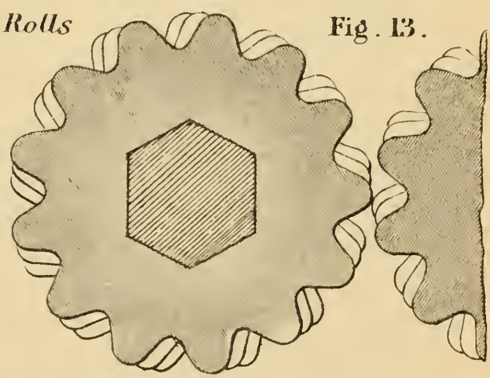
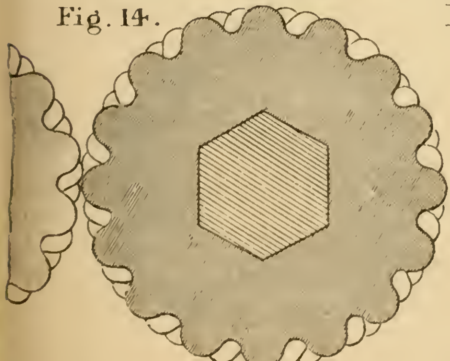
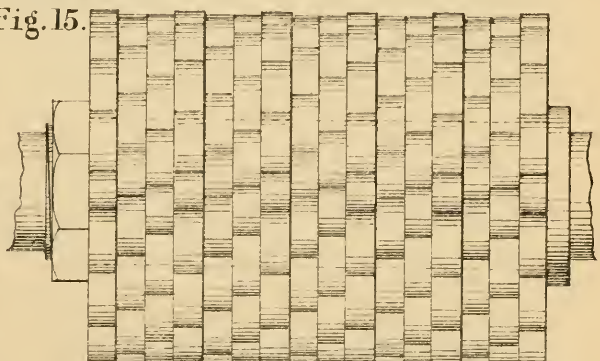


Fig. 14.



Lower Rolls.

Fig. 15.



Scale $\frac{1}{12}$th 0 5 10 15 20 25 *Inches.*

Indicator Diagrams from Steam Engine

Fig. 16. *Diagrams taken while driving both mills.*

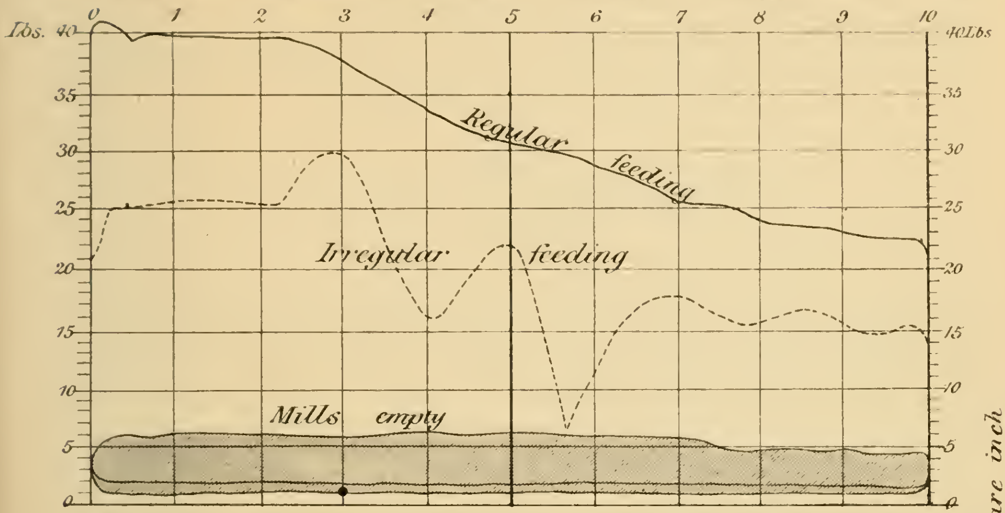


Fig. 17. *Diagrams taken while driving one mill only.*

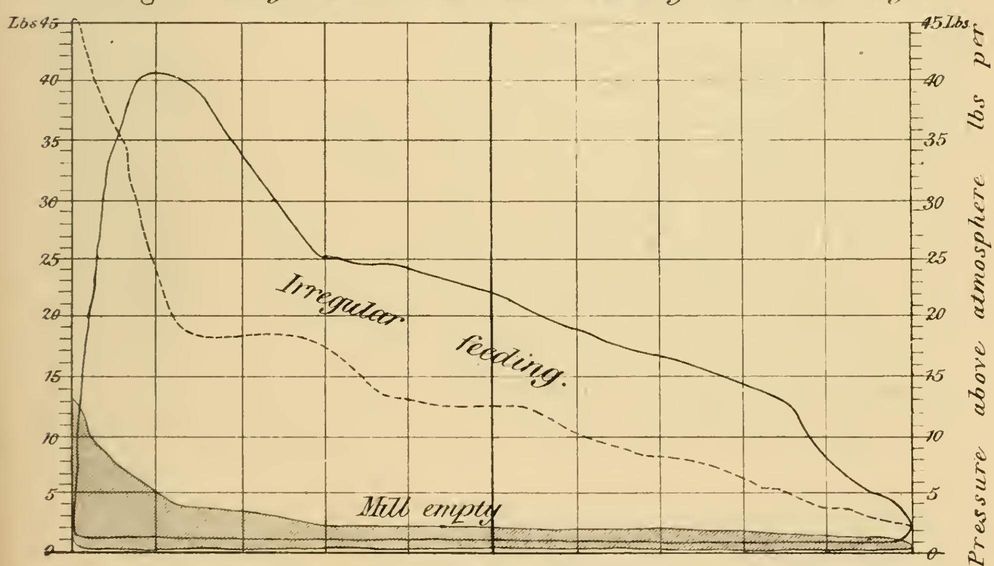
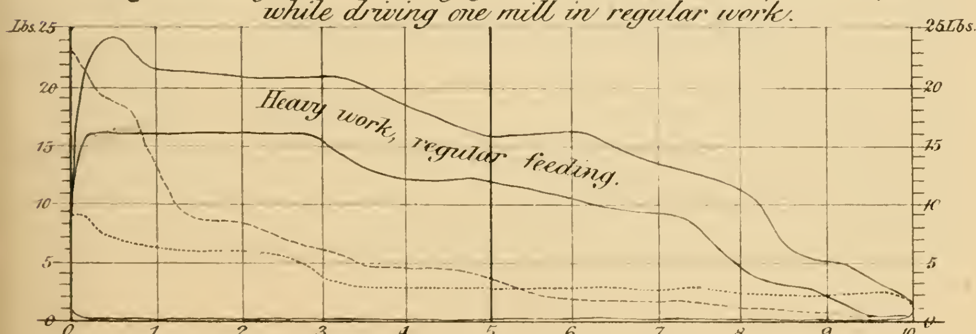


Fig. 18. *Diagrams showing greatest variation in power required while driving one mill in regular work.*



(Proceedings Inst. M. E. 1860. Page 234.)

DESCRIPTION OF A MACHINE FOR DRILLING INSTEAD OF PUNCHING WROUGHT IRON PLATES.

By Mr. JOHN COCHRANE, of Dudley.

The Drilling Machine described in the present paper was designed for the purpose of drilling a large number of holes in wrought iron plates, in a case where it was considered impracticable to punch the holes with sufficient accuracy. The plates are required for the construction of the two main side girders of the new railway bridge over the Thames at Hungerford, the spans of which are 154 feet clear; and as the bridge has to carry four lines of railway without any intermediate girders, the two side girders are required to be of very great strength, and are therefore being constructed of as many as five plates, each $\frac{5}{8}$ inch thick, besides four rows of 6 inch angle irons, rivetted through with inch rivets so as to form one plate of great strength and soundness. Hence the necessity that the holes in the several plates should correspond with perfect accuracy; and also that they should be truly parallel or cylindrical through each plate, so as to ensure their being completely filled by the rivets when rivetted up, which with more than three thicknesses is impracticable when the holes are punched, as they are then always larger on one side of the plate than the other.

The machine is shown in Plates 39 to 42: Figs. 1 and 2, Plate 39, are a front elevation and plan; and Figs. 3 and 4, Plates 40 and 41, are longitudinal and transverse sections to a larger scale. The plate to be drilled is placed on the table A, and surrounded by a wrought iron frame securely bolted on the table, within which the plate is made fast in the proper position by set screws at each corner, being supported underneath upon four longitudinal bearers and held down above by three transverse bars. The table A is guided by the two end frames B, and is raised by water pressure by means of the two

cylinders C fitted with rams D. The water pressure employed for raising the table up to the drills when a fresh plate has been fixed is given by a tank placed at a suitable height above the machine, from which the water is admitted by a two-way cock through the pipe E to the cylinders C. This pressure is not sufficient to make the drills act, but the necessary pressure against the drills is obtained by an accumulator, consisting of an upright cylinder, fitted with a plunger weighted to the required amount. The two-way cock from the tank is closed and the valve from the accumulator opened, and the drilling then proceeds; as soon as it is completed, the valve is closed, and the cock opened to the waste pipe, so that both pressures being removed the table falls by its own weight the desired distance, and the drilled plate is removed to make room for another. By this arrangement the heavy pressure of the water in the accumulator is not wasted in raising the table up to the drills, but is reserved for giving the required working pressure in drilling. The weight of the table is partly counterbalanced by the balance weights F, in order that it may be raised with sufficient rapidity up to the drills when the plate has been fixed ready for drilling; but sufficient preponderance is left to enable it to fall away quickly enough from the drills when the water pressure is removed.

The drills G are carried in two girders at the top of the machine, and driven from the two horizontal shafts H through the intervention of the bevil wheels and vertical shafts I, as shown in Figs. 3 and 4, Plates 40 and 41. In designing this machine cost had of course to be considered, and it was necessary to compensate by a saving in time for the greater expense of working occasioned by drilling instead of punching the plates. The machine is therefore arranged so as to drill all the holes in one plate simultaneously; there are eighty holes in each plate, 1 inch in diameter, arranged in four rows of twenty holes each; each of the two horizontal driving shafts H drives ten vertical shafts I, and each vertical shaft drives four drill spindles G, the pinions of which are fixed at different levels around the centre vertical shaft I so as to run clear of one another. The bushes at the lower end of the drill spindles are made of wrought iron, bevilled and faced with steel at the bottom to receive the upward pressure put

upon the drills in working, as shown enlarged in Fig. 5, Plate 42. These bushes are bored out to $\frac{1}{8}$ inch larger diameter than the drill spindles, with the exception of about $\frac{1}{2}$ inch length at the bottom, which is sufficient length of guide to ensure the drills running steadily; for when the machine was first got to work it was found that the drill spindles became chafed in running, by contact with the entire length of the bushes, and the latter were therefore bored out as described, without any diminution of steadiness in working; the space thus left in the upper part of the bush forms an oil chamber by which the shoulder of the drill spindle is kept constantly lubricated. The drills have tapered shanks fitting into the sockets of the spindles and secured by set screws, as shown in Fig. 5, so as to admit of any drill being speedily replaced in case of injury, or removed for sharpening. The simultaneous lubrication of all the drills while in work is effected by the plate being immersed in soap suds, which are confined within the frame that surrounds the plate and drawn off through pipes at the sides when required.

In ordinary drilling machines the time when the drills are most frequently broken is just when they are coming through the plate, when there is not enough thickness of metal left to stand the working pressure on the drills; and in order to provide against injury to the drills at that time in the present machine, there are four spiral buffer springs K, shown enlarged in Fig. 5, Plate 42, fixed in the upper frame and pressing on the corners of the table A, which oppose an increasing resistance to the upward pressure of the rams D; so that the pressure on the drills is gradually diminished as they work through the plate, and the table comes in contact with a fixed stop as soon as the drills are completely through, which prevents them from entering the table itself. The springs admit of adjustment in height according to the length of the drills, so as to allow for variation arising from wear of the drills by work.

The use of water pressure was adopted for raising the table of the machine, because it is important to raise and lower it with rapidity until the plate comes against the drills, when the pressure is required to be greatly increased to make the drills act. Had the lifting of the

table been performed by gearing, much time would have been lost: for the feed would necessarily have been slow, and it would have taken much longer to raise and lower the table than to drill the holes; and to arrange a variety of speeds would have rendered the machine so complicated as to be almost useless. With the water pressure the feed is under perfect control, and is regulated to be slow or fast exactly as required. The use of water pressure also affords the means of accurately measuring the amount of pressure necessary to be put upon the drills to make them work, and it has been found by experiment that the most economical load on one drill is 5 cwts., making a total upward pressure of 20 tons on the table of the machine, which is obtained by loading the ram of the accumulator with cast iron weights to the required extent. The drills are driven at a speed of 40 to 50 revolutions per minute, and at this speed the entire 80 holes of 1 inch diameter are drilled through a $\frac{5}{8}$ inch plate within 15 minutes, in the most perfect manner and without difficulty. The drills stand very well, being found to last on the average 10 hours without grinding. There is no necessity for previously marking the holes, but the plates are simply put on the table of the machine and adjusted by the set screws. The truth of the work is so complete that a number of the plates are put together indiscriminately, and four turned pins passed through the corner holes, when the lot are put on a planing machine and the sides and ends planed to gauges. The power required to drive one machine with 80 drills is about 10 horse power, the machine being driven by bands and pulleys on opposite ends of the two horizontal driving shafts H, Fig. 1. The accumulator is kept charged by a pair of 1 inch pumps worked from the ordinary shafting by eccentrics.

The present machine is constructed to drill the holes in each row at 4 inches apart, centre to centre, and the plates thus drilled are for the top flange of the bridge girders; but to give the camber required in the girders, the holes in the plates for the bottom flange have to be at 3·995 inches apart, so that a second machine is required for these plates. In the ordinary mode of punching by template however, so small a difference in the distance of the holes could not be practically carried out. The arrangement of the plates in the top flange of the

girders is shown in Figs. 6 and 7, Plate 42; Fig. 6 is an edge view of the flange, showing the successive layers of plates breaking joint transversely, (the thickness of the plates being exaggerated four times); and Fig. 7 is a plan showing the arrangement of the plates in each of the five layers breaking joint longitudinally.

This machine has now been at work for about two months, and has so thoroughly answered the purpose intended that two others are being completed as rapidly as possible.

Mr. J. Cochrane showed a specimen of a plate with the holes drilled by the machine, and one of the drills used. He explained that in the girders for which the plates were required all the plates were arranged to break joint transversely of the girder, so that there were no additional covering plates at the joints, but four thicknesses of plate gave the calculated strength of the girder, and the fifth plate was then added to take the place of covering plates. As the flange was too wide to be made in a single plate, it was formed of two plates laid side by side, a wide plate with 4 rows of holes and a narrow one with two rows, which were alternately reversed so as to break joint longitudinally as well as transversely. This construction required the plates to be very accurate in dimensions so as to fit exactly together, which would have caused considerable trouble and expense in the ordinary mode of work with punched holes: but with the present machine the holes were drilled with such absolute accuracy and uniformity of pitch in every plate, that the plates were simply put upon the drilling machine without any special adjustment, and for planing the edges afterwards they were adjusted on the planing machine by four turned pins put through the corner holes; the edges were planed down to a gauge from the side of these turned pins, so that the distance from the pins to the edges was just half that between two adjoining holes; consequently when the plates were put together in the girder the two half spaces made up exactly the uniform pitch of the rivet holes in the five thicknesses of plates, throughout the whole

length and width of the girder. A length of about 70 feet of the girder flange was now laid together at the works, which the members would have an opportunity of seeing the next day, as well as the drilling machine in operation; the holes in the plates fitted so accurately throughout that a 1 inch pin could be driven through the set of five thicknesses at any hole with a light hand hammer.

Mr. T. Dunn asked whether there was not a difficulty in getting the drills to stand equally over the whole surface of the plate; he would have feared there would be frequent delays from some of the 80 drills getting dulled and not cutting properly.

Mr. J. Cochrane replied that there was very little difficulty in practice from the drills failing, for the men soon found out those that stood the work well, and set aside the softer ones to be tempered again to a harder edge. The good drills stood for a whole day's work of 10 hours without grinding; and the pressure was so uniform and steady that the drills cut very regularly and smoothly, turning out long spiral shavings like the specimens shown. The principal difficulty experienced was from variation in the hardness of the plates, and occasionally a harder plate would dull some of the drills, which had then to be replaced; but a stock of 20 or 30 spare drills was kept ready for use, and any drill was easily changed in a few moments by simply slacking the set screw and tapping the drill, when it dropped out of the socket which was slightly tapered; the table of the machine was lowered for removing the drill, and raised again as soon as the new one was fixed.

Mr. W. Richardson asked whether any superior quality of steel was used for the drills, to enable them to stand the work better; and whether Mushet's steel had been tried, as he had heard it was of better quality and gave a more durable cutting edge that stood the work longer than ordinary steel without grinding up again.

Mr. J. Cochrane said they had used only ordinary cast steel at present for the drills, but were now trying some experiments with other steel, and he expected might succeed in making them stand probably two days instead of one before grinding up again.

Mr. C. Markham referred to the Jacquard punching machine, which he had seen at work at the Canada Works, Birkenhead,

punching the plates for the Victoria bridge at Montreal; it was constructed for punching a long row of holes simultaneously, giving the means of adjustment to any required variation of pitch, and the punching was done with remarkable truth and accuracy, and with a rapidity which rendered the machine admirably adapted for bridge work. The Jacquard machine was no doubt a very costly one; but in great works such as the Britannia and Victoria bridges the first cost was of comparatively little consequence. He feared the expense of drilling the holes would be found very great.

Mr. J. Cochrane believed the cost of the Jacquard machine was £3000 or £4000, which would limit its application to a work of the most extensive kind, such as the bridges alluded to; but it was adapted only for punching, and punched holes were so inferior in accuracy to drilled holes as to be quite inadmissible in the present case.

Mr. J. Fernie considered they were greatly obliged for the description of the drilling machine: this was a new application of drilling to a class of work in which it would prove of great value, being so far superior in accuracy to punching. However carefully punching might be done, a punched hole was never so true as a drilled one; and besides the injury done to the iron in drifting the holes afterwards to make them fit, the pressure on the plate in punching put a strain upon it and made it slightly hollow all round the hole, which prevented the plates being closed up so tight in rivetting. He thought drilling would be particularly advisable for the sides of fireboxes in locomotive boilers, where accuracy in the rivet holes was of so much importance, on account of the plates being required to fit correctly in all directions. Some of the locomotive boiler ends on the Midland Railway had lately been made with the holes drilled instead of punched, and it was found that the expense of drilling was but little more than that of punching, while the drilled plates went together beautifully, saving all trouble of rimering or drifting to make them fit.

Mr. J. Cochrane observed that it was well known to be impossible to punch a cylindrical hole, on account of the bolster being necessarily somewhat larger than the punch, so that the hole must be taper, as the bottom end of the burr punched out filled the bolster; in punching 1 inch holes through a $\frac{5}{8}$ inch plate, the diameter of the holes would be

about $\frac{1}{16}$ inch greater on the underside of the plate than on the upper side. In rivetting only two plates together the holes could be matched with the small ends next each other, as in ordinary boiler work; but with three or more plates it was practically impossible to make the rivet fill the hole by hand rivetting, on account of the cones, and the only way of doing it then was by a rivetting machine. He fully agreed in the importance of adopting drilling instead of punching for boiler plates, and thought their strength would be much increased thereby; in a great number of cases of boiler explosions the plates had given way through a rivet hole, apparently in consequence of the iron having been strained by forcing the punch through, and often further weakened by the rough drifting process.

Mr. E. A. Cowper observed that drilled holes were undoubtedly far more true than punched holes could possibly be, and were particularly suitable for the work described in the paper, on account of the great accuracy necessitated by the plates having all to break joint to such an extent. He enquired what was the cost of drilling by the machine as compared with punching the holes. There was of course a saving of expense in fitting the work together when the holes were drilled; for in punching, the iron became stretched at each hole, and a long angle iron might be stretched in this way as much as $\frac{1}{2}$ inch in 10 feet length; so that a different template had to be used for marking out the holes in the angle iron, in order to allow for the stretching. The Jacquard punching machine that had been referred to was not to be compared with the drilling machine in point of accuracy: but where punching was good enough, it was useful for punching a large number of holes at a time, and especially for punching plates to a particular pattern, as where a certain number of the holes had to be omitted in some of the rows.

Mr. H. C. Hurry asked how a uniform length of the drills was ensured, and whether their unequal wear did not cause some difficulty, as they would then not all bear on the plate at starting. He suggested whether the machine could be arranged for altering the pitch of the holes, that it might admit of more general application; for it would materially effect the expense of drilling if a special machine were required for every different pitch.

Mr. J. COCHRANE replied that no difficulty was occasioned by difference of length in the drills, since the feed by the water pressure was completely under control. On first getting the machine to work, the drills had been made of different lengths, because there was a deficiency of power for driving the machine; so that some of the drills were nearly through before others had begun cutting, thus saving power at the expense of time. The buffer springs acted so perfectly in easing the pressure when the drills were coming through, and the admission of water could be so exactly regulated, that it was possible to work with one drill only: the time of drilling was of course affected by having different lengths of drills, and the longest must not be so long as to go into the table of the machine.

As to the comparative cost of the work, with 80 holes in each plate drilling was no doubt much cheaper than punching; but with only half the number of holes the cost would probably be about the same as in punching. Drilling was however much safer and more accurate, and caused a great saving in putting the work together, an advantage of particular importance in the case of work manufactured for sending abroad for foreign railways: the increased cost in fitting up the machine at first would be fully repaid by the superior work produced, and would prove the cheaper plan in the end.

Mr. C. MARKHAM asked how long it took to put the plate into the machine and remove it when drilled, besides the time of drilling.

Mr. J. COCHRANE replied that 5 minutes were quite enough for fixing and changing the plate, making 20 minutes the total time for each plate; but often only 4 or 3 minutes were occupied, instead of 5.

Mr. W. RICHARDSON said that in the cotton spinning machinery manufactured at Messrs. Platt's works a large number of holes had to be drilled only $\frac{5}{8}$ inch asunder; and as the drill spindles could not be geared nearer than every five holes, after one lot of eight holes had been drilled the drilled carriage was moved forwards $\frac{5}{8}$ inch and eight more holes were drilled, and so on until the four intervening series of holes were all drilled, when the carriage was moved on and a fresh series of holes commenced. The holes had to be drilled conical, and to make them all the same size the bottoms of the drill spindles were furnished each with a screw, so as to vary the depth of the drill

sockets; and the drill sockets were made parallel instead of taper, with two set screws on opposite sides in order to avoid the drill being thrown out of truth by the pressure of a single set screw on one side.

Mr. J. Cochrane said that in the machine described in the paper, with 4 inches pitch for the drills, the space for the driving pinions was so close that there was barely room for the brass collars on the top of the spindles; and the collars had to be reduced to less than $\frac{1}{8}$ inch thickness to give sufficient clearance for the pinions. They were so close run for room that in the second machine, for drilling the plates of the bottom flange of the girder, where the pitch of the holes was only 3·995 inches, it was decided to drill only half the holes at a time, and then shift the plate for drilling the remaining holes. It would be very expensive to introduce an arrangement for altering the pitch of the drills, for this would add greatly to the complication of the machine; it was cheaper to cast a fresh top frame for a different pitch, and fit it complete with bushes for the drill spindles, but the same spindles and pinions could be used when there was only a little difference in the pitch, as in the present case.

Mr. C. Little enquired whether any experiments had been made on the comparative strength of drilled and punched plates.

Mr. J. Cochrane had not tried the comparative strength, but understood that in some experiments made by Messrs. Sharp the strength of boiler plates was found to be materially increased by having the holes drilled instead of punched.

The Chairman had no doubt punched holes could not be so good as drilled ones, and the men were seldom careful enough in setting out the holes and holding the plate correctly under the punch. But by drilling much greater accuracy was obtained, and he thought the plan of drilling would be highly advantageous for boiler making and ship building, in both of which there was at present room for great improvement.

He proposed a vote of thanks to Mr. Cochrane for his paper which was passed.

The following paper, communicated through Mr. Alexander B. Cochrane of Dudley, was then read:

DESCRIPTION OF THE ROUND OAK IRONWORKS.

By Mr. FREDERICK SMITH, of Brierley Hill.

The following description of the Round Oak Ironworks, recently erected by the Earl of Dudley, has been prepared with a view of showing what progress has been made in South Staffordshire in the manufacture of malleable iron, the main object in the arrangement of the works having been to combine convenience with economy. The works were planned throughout before any part was commenced; and endeavours have been made to collect together in this plan many of the most recent improvements.

Fig. 1, Plate 43, shows a general plan of the whole works, which consist of a main building ABC, 480 feet long, 138 feet wide, and 20 feet high to the underside of the eaves; with two warehouses DD, each 120 feet long and 40 feet wide. The works are divided into three parts, of which the centre portion A contains the forge rolls, hammers and shears, with the engine for driving them, as shown in the enlarged plan, Fig. 2, Plate 44. The second portion B, Figs. 1 and 2, contains the 21 inch plate mill and 16 inch bar mill, shears and saw, with their engine. The third portion C, Fig 1, comprises the 12 inch bar mill and 8 inch guide mill, shears and saw, and the engine driving them; together with the 7 inch wire mill and engine.

The forge A, Figs. 1 and 2, comprises two hammers EE, two trains of forge rolls FF, and two cutting-down shears GG, driven by the engine and gearing H, which are shown in Fig. 3, Plate 45. The engine H is high pressure, non-condensing, and horizontal, having a cylinder 30 inches diameter and a stroke of 3 feet, making 60 revolutions per minute. It is seated upon a cast iron bed plate, bolted down to a foundation of framed timber balks, the gearing to which it gives motion

being similarly secured : the crank shaft of the engine is 12 inches diameter in the bearings, and the flywheel 20 feet diameter weighing 21 tons. The principle of the long equilibrium slide valve has been applied in the steam chest with good results; in other respects the engine is of the ordinary horizontal construction. Steam is supplied from the five cylindrical egg-ended boilers I, Figs. 1 and 2, each 5 feet 6 inches diameter and 32 feet long, of plates $\frac{1}{2}$ inch thick : these are set in brickwork in the manner commonly known as "oven" setting, the boiler being supported at the sides by wrought iron brackets resting upon the brickwork, and the heat from the grate being carried straight along the under surface and sides and thence direct to the chimney. The firegrate is $7\frac{1}{2}$ feet long by 6 feet wide, giving an area of 45 square feet, and the heating surface in each boiler is about 260 square feet; the pressure of steam is kept at about 40 lbs. per square inch. The feed water passes through a heater, which utilises a portion of the exhaust steam and raises the temperature of the feed to about 90°.

Motion is communicated from the engine shaft to the forge rolls FF by means of the pinion J, Fig. 3, 6 feet diameter and 15 inches wide in the teeth, gearing into the wheel K 16 feet diameter, and reducing the speed of the crank shaft to 23 revolutions per minute for the trains of rolls FF. These trains contain each three pairs of rolls 21 inches diameter, cut in the usual form for the production of puddle bars of sizes ranging from 12 inches to 2 inches wide, as well as for billet iron from 3 inches to 1 inch square. To get all the sizes intermediate between 12 inches and 2 inches, two sets of rolls are employed, one pair ranging from 12 inches to 9 inches, the other from 9 inches to 2 inches. The roll frames or housings are carried on strong cast iron bedplates bolted down to timber balks laid upon brickwork. The roll pinions LL are 21 inches diameter, with teeth 15 inches wide and $4\frac{7}{8}$ inches pitch.

The forge hammers EE, Fig. 3, are driven, one by a strap direct from the engine shaft, the other by a toothed wheel gearing into the driving wheel K of the forge rolls. Fig. 5, Plate 46, shows an enlarged elevation of the forge hammer. The cam is of cast iron, 7 feet diameter over all and $2\frac{1}{2}$ feet wide, making 15 revolutions per minute : the shaft is of cast iron 16 inches square. The circumference

of the cam carries 4 lifters or arms of wrought iron, giving the hammer 60 blows per minute. The helve is 10 feet long and $1\frac{1}{2}$ feet deep, weighing $6\frac{1}{2}$ tons; the hammer weighs 11 cwts., the anvil 12 cwts., and the anvil block 18 tons; this together with the bearings of the cam shaft and helve is firmly bedded upon three courses of oak balks laid crosswise, resting on a bed of concrete 2 feet thick, put in upon a stiff clay bottom.

The shears GG, Fig. 2, shown in elevation in Fig. 4, Plate 45, are used for cutting down iron for piling; they stand with their jaws raised 2 feet above the floor line, and are worked by a wrought iron connecting rod attached to a crank driven from the engine shaft by bevil wheel and pinion. The connecting rod to these as well as to all the shears throughout the works is underground and out of the way, as shown in Fig. 4, and thus a clear space round the shears is secured.

In the second portion B of the plan, Figs. 1 and 2, stand the 21 inch plate mill M, the 16 inch bar mill N, the shears O, and the saw P; these are all driven by the engine Q, which is similar in every respect to that described for the forge, and is supplied by five boilers R of the same size and construction.

The plate rolls M are driven by means of gearing, giving them a speed of 27 revolutions per minute. The train contains two pairs of rolls 21 inches diameter, one pair being soft, 5 feet 8 inches long; the other pair hard, 4 feet 10 inches long. The soft pair has its upper roll supported and held up against the setting screws by means of a lever and counterbalance weight working underground, and exerting an upward pressure upon the necks of the roll somewhat greater than its own weight: while the upper of the hard pair of rolls has no lever and acts by its weight alone. The roll pinions are 21 inches diameter, 15 inches wide, and $4\frac{7}{8}$ inches pitch of the teeth. This mill is capable of producing plates of any thickness from No. 16 wire gauge or ·065 inch to $1\frac{1}{4}$ inch, and of a width not exceeding 4 feet 2 inches in the hard rolls, and 5 feet 2 inches in the soft rolls for thicknesses above $\frac{1}{4}$ inch.

The train of the 16 inch bar mill N comprises three pairs of rolls making 60 revolutions per minute, whose respective lengths are—

roughing rolls 5 feet 9 inches, finishing rolls 4 feet, strip rolls 1 foot 4 inches. The housings and pinions are arranged to admit of the introduction of 18 inch rolls into this train on occasion. The general character of work done ranges as follows :—

Flats	from	12	inches to	3	inches wide.
Rounds	,,	$6\frac{1}{2}$	,,	$1\frac{1}{2}$	,,
Angle and T irons	,,	6	,,	3	,,
Strip		12	,,	3	,,

The cropping shears O are similar to those in the forge already described. The circular saw P is 3 feet 6 inches diameter and $\frac{1}{8}$ inch thick. It is set in motion when required by admitting steam to a rotary emission engine attached to the saw spindle : this method has been adopted in preference to gearing, as the saw is wanted only occasionally. It is fitted with a moveable table at the level of the floor, which brings the bar laid upon it in contact with the saw by means of a lever.

The third portion C of the plan, Fig. 1, comprises the 12 inch bar mill S, the 8 inch guide mill T, with saw and shears, driven by the engine U ; and the 7 inch wire mill V and engine W. The engine U driving the 12 inch and 8 inch mills is vertical, having a cylinder 24 inches diameter and a stroke of 2 feet, making 90 revolutions per minute : it is direct-acting, and the whole of it except the crank shaft is fixed underground. Steam is supplied by four boilers X of the same size and construction as those of the forge.

The 12 inch bar mill S contains one train consisting of three pairs of rolls ; of these the roughing rolls are 5 feet long, finishing rolls 3 feet 1 inch, and strip rolls 1 foot. They make 90 revolutions per minute, and are driven by direct action. These rolls turn out from 3 inches to $1\frac{1}{4}$ inch iron.

The 8 inch guide mill T contains roughing rolls 3 feet 1 inch long, finishing rolls 2 feet 1 inch, and guide rolls 8 inches, making 240 revolutions per minute, and turns out from $1\frac{1}{4}$ inch to $\frac{3}{4}$ inch iron.

The same engine also gives motion to one pair of cropping shears for the 12 inch mill, and two pairs of cropping shears for the 8 inch mill. These mills have a second circular steam saw like that previously described.

The 7 inch wire mill V comprises three pairs of rolls, 2 feet 7 inches, 1 foot 6 inches, and 8 inches long respectively, making 300 revolutions per minute, and turns out $\frac{3}{4}$ inch to $\frac{1}{2}$ inch iron. This train will roll wire through guides, and hand-rolled rivet iron. By a simple arrangement of the gearing the speed of the train can be reduced to 200 revolutions per minute, to allow for a change to hand rolling. The engine W giving motion to these rolls is high pressure and horizontal, with a cylinder 15 inches diameter and a stroke of 2 feet, and makes 90 revolutions per minute. The two boilers supplying the engine with steam are raised about 9 feet from the ground upon cast iron stanchions which support the brickwork setting; they are heated by the waste heat from two of the mill furnaces. The end of the setting abuts on the chimney of a heating furnace, from which a flue is carried completely round the boilers, returning again to the chimney.

The forge A contains 27 puddling furnaces arranged in pairs, as shown at YY upon the plan, Figs. 1 and 2, Plates 43 and 44. A longitudinal section and sectional plan of one of the puddling furnaces are given in Figs. 6 and 7, Plate 46. The general dimensions of the furnaces are given in the table below. The body of each furnace is lined with firebrick 9 inches thick, the chimney and flue being of $4\frac{1}{2}$ inches firebrick. The bridge stands one foot 4 inches above the firebars. The puddling plate is of cast iron 2 inches thick, protected by a cinder flooring prepared by fusing best scrap iron in the furnace until it parts with its cinder, which is allowed to flow over the bottom until it is about 3 inches thick. The sloping sides which give the basin-shaped form to the floor indicated upon the plan are made by heaping up calcined tap cinder or "bull-dog" around the sides of the puddling plate and fusing it into a mass: the wear and tear both of the floor and sides is daily repaired by the addition of small quantities of best scrap iron and bull-dog. The brickwork of each furnace is bound together by cast iron plates and bolts. The chimney is 36 feet high from the ground, and 22 inches square inside. The coal pens Z, Fig. 2, are of wrought iron plates, one to each furnace, close to the traversing railways.

The ball furnaces are similar in section to the puddling furnaces, but of larger size, and are made up with grit sand instead of cinder floors. They are used chiefly for work of a heavy description and for slabs for "best best best" iron. The 16 inch mill N, Fig. 1, contains three heating furnaces of similar section to the puddling furnaces, though of different size, with a sand instead of a cinder floor; they can heat piles from 1 cwt. to 20 cwts. each. Three heating furnaces of similar construction to the last supply the plate mill M; and beside them the mill contains also an annealing furnace for thin plates hardened in rolling, of sufficient size to admit large sized plates. The 12 inch mill S contains two heating furnaces with sand bottoms. The 8 inch mill T and the 7 inch wire mill V each contain two heating furnaces; those of the wire mill heat the steam boilers of the mill in the manner already described. The following are the principal dimensions of the several furnaces :—

Dimensions of Puddling, Balling, and Heating Furnaces.

Description of Furnace.	Length of Body.		Width of Body.		Size of Firegrate.					Height from firebars to roof.	
	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.		Ft.	Ins.	Ft.	Ins.
Puddling Furnaces	6	0	3	9	3	6	×	3	6	2	8
Ball furnaces.	7	0	5	6	4	0	×	3	10	2	8
Heating furnaces, 16 inch mill, and plate mill	7	6	6	0	4	9	×	3	10	2	8
,, 12 inch mill . .	7	0	5	6	3	10	×	3	6	2	8
,, 8 inch mill . .	6	6	4	6	3	10	×	3	6	2	8
,, wire mill . . .	5	6	4	6	3	10	×	3	6	2	8

The sides of the works are open, and the roof which covers 76,000 square feet contains louvres for ventilation, and passes off the rain water through the cast iron columns upon which it is supported. The floor is mostly covered with cast iron plates. All the buildings are on a level with the West Midland Railway, which passes close to the works; a branch from it ramifies into every part of the premises. The canal shown upon the plan, Fig. 1, is 23 feet below the general level of the works: hence the exports and imports can be carried either by

rail or water. If by the latter they pass along the incline and tunnel J, or up and down the water lift K, which is specially intended for raising pig iron to the pig yard when sent by boat; but the supply of crude iron to the works comes chiefly from the adjacent Level Blast Furnaces along the road over the cinder tip, level with the tunnel heads of the furnaces, which are thus level with the floor of the works. Finished iron can either be stacked in one of the warehouses DD, and loaded thence into railway trucks on the branch from the main line which runs through these buildings; or lowered by means of the incline and tunnel J to the canal side for shipment into barges. The boiler houses I, R, and X, are all roofed over; each of them has a chimney 120 feet high with a flue area of 7 feet 6 inches square at bottom and 4 feet 6 inches at top. The fuel for the boiler fires is shot out of the railway trucks into subterranean pens, down which it rolls almost to the mouths of the firegrates: the ashes from the boilers are also removed along an underground railway, and much of the heavy business of the works is thus carried on not only underground but unseen by a casual visitor; by this means much additional space and accommodation are gained. At L is the pattern shop and roll-turning shop, over which are two cast iron water tanks containing about 50,000 gallons, for supplying water to the entire works; these are fed by four pumps worked by a separate pumping engine and boilers below.

The following are the processes gone through in producing the different kinds of iron made at these works, known as "common," "best," "best best," and "best best best." "Common" iron is made from puddle bars of hot-blast mine pig, cut, piled, and heated with best coal for about an hour and a half in one of the bar mill furnaces, and rolled in the bar mill to the section required. "Best" iron is made from a mixture of cold and hot-blast pigs, but the top and bottom of the pile are of puddled iron that has been worked over twice at the hammer and forge rolls; so that all "best" iron is worked over at least twice, while the upper and lower parts of the pile are worked over three times. "Best best" iron also consists of a mixture of cold and hot-blast pig and is treated nearly the same as "best," only that the whole pile is worked over twice at the hammer

and forge rolls. "Best best best" iron is made entirely of cold-blast mine pig, and rolled out into $3\frac{1}{2} \times \frac{5}{8}$ inch bars. These are sheared into small snippings and then run in barrows to the ball furnace, where they are worked together into a ball of about 1 cwt. in the course of a few moments. The ball is hammered and re-heated in the furnace, hammered again and then put through the forge rolls; the bars produced by these rolls are then cut up and piled, heated at a bar mill furnace and rolled in the bar mill. In this process to form "best best best" iron it is heated five times, hammered three times, and rolled three times.

The following are statements of the usual waste of iron and consumption of coal and slack in the production of a ton of iron of the several qualities:—

Waste of Iron per ton of iron made.

Description of Iron.	Puddling Furnace.	Ball Furnace.	Mill Furnace.	Total.
	Per cent.	Per cent.	Per cent.	Per cent.
Common	9	...	10	19
Best	9	5	10	24
Best best	10	10	10	30
Best best best	10	{ 15 / 7 }	5	37

Coal and slack consumed per ton of iron made.

Description of Iron.	Puddling Furnace.	Ball Furnace.	Mill Furnace.	Total.
	Cwts.	Cwts.	Cwts.	Cwts.
Common	25	...	17	42
Best	25	12	17	54
Best best	25	18	17	60
Best best best	25	{ 30 / 18 }	17	90

In conclusion it may be remarked that it is a matter of importance to this country generally that manufacturers should devote their serious attention to the quality rather than the quantity of iron produced, or the prosperity of this most extensive branch of industry will have to yield to the vigorous efforts of foreign competition and of the United States in particular, who with their iron mountains of Missouri and their enormous coalfields are so energetically endeavouring to transfer to themselves the reputation at present enjoyed by this country in connexion with the manufacture of iron.

Mr. A. B. Cochrane thought the paper was one of much interest as a record of one of the largest ironworks in the South Staffordshire district; and of special value in the important particulars given in it of the waste of iron and consumption of fuel in making the different qualities of iron. The great increase both in waste of iron and in fuel consumed for producing the better sorts of iron made it clear that iron of the first quality could be obtained only at a proportionate increase in cost: this was a point that could not be made too clear: for at present it too often occurred in contracts that a superior quality of iron was required to be used, but the prices at which they were let were such that the iron itself could not be got at that cost, independent of the labour of manufacturing the work for which it was employed; and consequently such iron could not be employed in the work. It was highly desirable for the credit of the South Staffordshire district that it should be clearly understood that superior qualities of iron could not be obtained except at a considerably higher cost: and he believed there were in the district all the necessary requirements of coal, ironstone, and skilled workmen, for turning out as good a quality of iron as any in the country.

Mr. Sampson Lloyd noticed a peculiarity in the arrangement of the works as compared with most of those in the district, the steam for

the engines being obtained from horizontal boilers with separate fires, instead of from vertical boilers heated by the waste heat from the puddling furnaces as was ordinarily the case. The consumption of coal in the puddling furnaces would be just as much as when the waste heat was utilised for heating the boilers; and therefore there must be a considerable additional consumption for the boilers, which would increase the proportion of coal per ton of iron made. Though there was no doubt plenty of slack at hand for heating the boilers, yet every sort of slack was now made of value by different modes of using it; and if that consumed under the boilers were saved, it might perhaps be employed advantageously for other purposes.

Mr. W. A. Adams had been connected with some ironworks where the boilers were all heated by the puddling furnaces, on account of slack not being cheap there; but this was not a convenient arrangement, as the boilers were stopped whenever the puddling furnaces were stopped, and the heat fluctuated so greatly while the furnaces were in work that no regular supply of steam could be maintained. If slack had been cheap, they would have had the boilers heated independently, which would have been a much better arrangement.

Mr. Richard Smith observed that in the present case a great quantity of fine slack was made in the pits by the rib and pillar system of working, which the men used to leave on the floor of the mine till it accumulated sometimes to 12 feet thickness; till finally, from droppings of water from the roof, spontaneous combustion took place, and obliged them often to leave a fine side of work, causing a great loss. So great inconvenience was thus occasioned that it was decided on planning the new works it would be better to have separate boilers, independent of the puddling furnaces, in order to be obliged to burn the slack, that there might be a necessity for drawing it out of the pits, so as to prevent its accumulation in the workings. There was also the objection that had been mentioned against having the boilers heated by the puddling furnaces, the boilers being stopped whenever the furnaces were out of work; and this was a serious consideration in large ironworks, since it was essential to keep the machinery going regularly without fluctuations.

Mr. F. Smith said that by the complete arrangement of railway lines at the works the slack was brought away from the pits and dropped into the pens of the boiler fires at almost a nominal cost; and if not disposed of in this way it would cost as much to deposit it anywhere else. These reasons might not apply to other works, where there were not the same facilities for getting rid of the slack.

Mr. T. Dunn asked whether the old form of helves used in the works were preferred to steam hammers.

Mr. F. Smith replied that the helves were used in preference, because they could not be tampered with by the men: with a steam hammer the impurities contained in the iron could be wrapped up in the ball by gentle blows, instead of being all driven out; but by the heavy blows of the old helve all noxious matter was at once driven out and improperly puddled iron detected.

Mr. A. B. Cochrane considered the helve was decidedly preferable for shingling on that account, particularly for night work; as it precluded risk of inferior iron passing without detection, and could not be prevented from falling every time with the full force of blow.

Mr. Samuel Lloyd thought it was a great advantage to have a hammer that could not be controlled by the men, because then if the iron were not good it could not be worked under the hammer; but with a steam hammer, the men being paid by weight and the work kept on night and day, there was a facility for wrapping up a ball of imperfect iron to increase the total make; and in spite of all the care in overlooking the work, there might thus be bars of inferior quality mixed with the rest without its being known.

Mr. R. Pilkington used the steam hammer for shingling, and experienced no difficulty from inferior iron being worked up by it; the objection named would be obviated if the shifting gear were made to be locked up when the men were left for night work, so that the length of stroke could not be altered, and every blow of the hammer would come with the full force as in the ordinary helve.

Mr. W. Hall said at the Bloomfield Ironworks they had a large helve of 8 tons weight that was used for shingling, but with large slabs of iron weighing 16 or 18 cwts. there was only 2 or 3 inches height left for the hammer to fall, so that the first blows had but

little force; and he thought on that account a steam hammer was better, giving a greater height of fall, while all objection to its use would be removed by having the shifting gearing locked up. One of the hammers shown in the drawing appeared to be driven by a cam on the last shaft of the train of wheels; and he thought the other plan of driving by a strap was preferable, for, should the engine ever run, the hammer falling on the arms of the cam was likely to cause a breakage of teeth when driven by gearing.

M. F. Smith said that one of the hammers was driven by gearing, and the other by a strap from the main shaft, hut there was a heavy flywheel which sufficiently equalised the motion; and no objection had been experienced with the gearing.

The Chairman moved a vote of thanks to Mr. Smith for his paper, which was passed.

The following paper wàs then read :—

ON THE APPLICATION OF THE DECIMAL SYSTEM OF MEASUREMENT IN BORING AND TURNING WHEELS AND AXLES.

By Mr. JOHN FERNIE, of Derby.

In a former paper read at a previous meeting of this Institution the writer stated some of the advantages to be derived from the application of the Decimal system of Measurement to various descriptions of mechanical engineering work, amongst which was mentioned the securing of Wheels on their Axles, as one of the many operations where it might be advantageously applied. In ordinary railway practice the wheels are pressed on the axles by the hydraulic press, the wheel boss being bored so much smaller than the axle that a certain amount of tension is put on the boss such as experience may have shown to be safe. But this amount has always been empirical, and vaguely designated as a bare 16th or a full 32nd of an inch; and nothing could more forcibly show the necessity of a new system than the measurement of the actual dimensions of the gauges hitherto in use, in which it has been found that the degree of tightness or the difference in diameter between the wheel boss and the axle ranged from ·003 to ·012 inch. The writer's object has therefore been to fix standard sizes for boring and turning, so that uniformity may be attained; and with this view a number of trials were made, which are detailed in the present paper.

The first step was to make two gauges, one 6·000 inches and the other 5·988 inches long: to the larger of these an axle was carefully turned, and to the smaller a wheel carefully bored, the difference of diameter being thus ·012 inch; the wheel was then pressed on the axle, and again pressed off. There was considerable difficulty in pressing it off, three men on a long lever putting on a pressure of at least 80 tons, and it was only after some violent blows of a sledge

hammer that the wheel made the first start; after a few such starts it came off easily. After being pressed off, the condition of the axle end as well as of the boss led to the conclusion that an excessive strain had been applied, injurious to both wheel and axle; this appeared more fully on measurement. The axle was reduced ·002 inch in diameter for nearly a third of the length in the wheel, and ·001 inch at the middle of the length, whence it gradually tapered off to its original size; the surface of the axle was also cut, though it had been well oiled before pressing the wheel on. The boss on a careful measurement was found to have sustained a permanent stretch amounting to ·006 inch and was slightly taper, and also slightly cut like the axle.

It was considered that the degree of tightness required was one that would not inflict any permanent injury on the wheel or axle; and in order to determine the amount the further experiments given in the accompanying table were made. From the fifth experiment it will be seen that with a difference in diameter amounting to ·003 inch, and with the wheel very carefully bored and the axle very carefully turned, the wheel is pressed on and off without the boss retaining any permanent stretch or the axle sustaining any injury. In addition however to great care in the boring and turning, it is necessary to get very smooth surfaces; for in some of the trials made it was found that when the wheels and axles were turned with a narrow pointed tool, leaving the surfaces slightly rough, the tops of the surfaces or threads were ground off, and they would not stand pressing on or off so well as when they were turned very smoothly. The greatest difficulty in working to such small dimensions consists, not in the want of skill of the workmen, but in the roughness of the present machinery: some lathes have a strong bias to run taper, and some run slightly oval; there may also be some want of uniformity in the nature of the material, hard places to grind away the tool or to press harder against it and so make it work taper or oval. For these reasons, although ·033 inch appeared to be sufficient difference in diameter in the best work, the writer was ultimately led to adopt ·005 inch, the result of which is a very small permanent stretch of the wheel boss, as shown in experiments 3, 4, and 6; but he believes this is more than compensated for by the contraction of the tyre, which throws a considerable amount of

Experiments on Difference in Diameter in Boring and Turning Wheels and Axles.

No. of Experiment.	Length of Boss.	Diameter of Boss.	Diameter of Axle.	Difference in Diameter.	Permanent Stretch of Boss	Remarks.
	Inches.	Inches.	Inches.	Inch.	Inch.	
1	7·0	5·988	6·000	0·012	0·006	Very tight. After pressing off, wheel and axle cut and slightly taper.
2	7·0	5·992	6·000	0·008	0·004	
3	7·0	5·995	6·000	0·005	0·002	
4	7·0	5·995	6·000	0·005	0·003	Very smoothly bored and turned.
5	7·0	5 997	6·000	0·003	0·000	Ditto; rather too easy à fit.
6	7·0	6·495	6·500	0·005	0·001	Axle slightly taper; diameter at 1·5 inch from outer end . . 6 498 inches.
7	7·0	6·493	6·500	0·007	0·003	Tight. Ditto ,, ,, 6 498 inches.
8	7·0	6·491	6·500	0·009	0·005	Very tight. Ditto ,, ,, 6·497 inches.

compression on the boss. With ·005 inch difference in diameter the wheel is pressed easily on the axle with a pressure of about 20 tons; and the permanent stretch as measured in a number of wheels tried amounts to from ·001 to ·002 inch. As it is almost impossible to secure a perfectly parallel hole through the boss, the lathe should be so arranged that the largest size is the entering side of the wheel; and if properly managed a good fit from end to end of the hole may be obtained.

In securing the outside cranks on the axle ends, it has been found by experiments similar to those given in the table that instead of an allowance for shrinkage amounting to ·030 inch on a diameter of 6 inches, ·015 inch is amply sufficient; and in pressing crosshead spindles of 2·5 inches diameter into their place, a difference in diameter of ·004 inch is sufficient; while levers with 3 inch holes require a difference of ·001 inch, when they are to be driven on with a lead hammer.

From a lengthened experience of this decimal system of measurement, the writer is more than ever satisfied of the importance and practicability of carrying out Mr. Whitworth's excellent system into the workshop: workmen soon learn to work to the fine measurements, and no difficulty has been experienced in this respect. Gauges such as are used for standard sizes are made in the ordinary way from standard end measures, by which the gauges in use can be verified or new ones supplied at any time. For axle turning the gauges are of steel, of the old horse-shoe shape, and are allowed to drop over the axle by their own weight; for wheel boring they are made of flat steel, with the ends bluntly rounded over, and are made to pass through the boss with an easy pressure. There is no difficulty in working with these gauges to one thousandth of an inch. Standard gauges for wheels and axles, levers and shafts, made by Mr. Whitworth's measuring machine, can be obtained giving the difference in size as above described; and these need not go into the workshop but can be kept for reference, others being made from them for ordinary wear and tear in the turning shop; and thus standard sizes may be got and kept, which will be of great value.

The decimal measuring machine constructed by the writer at the Midland Railway Works, Derby, and employed for producing the various standard gauges for use in the workshops, is similar in principle and construction to Mr. Whitworth's measuring machine described at a former meeting of the Institution; the principle of its construction being that of end or contact measurement instead of line measurement, depending on the sense of touch instead of sight.

The machine is shown in Plates 47 and 48. It consists of a strong and heavy cast iron bed A, Fig. 1, long enough to take in a measure of 100 inches, shown in section enlarged to one quarter full size in Fig. 6, having a right-angled V groove in the top surface, in which the gauges to be measured are laid. At either end are the adjustable centres B and C: the centre B is advanced or drawn back by the screw D and nut E, Fig. 5, the latter being held stationary in the end of the bed A, and turned by the handwheel F of 10 inches diameter. The screw D is made with as nearly as practicable 10 threads per inch, and the circumference of the handwheel F which is 2 inches wide has a spiral line chased upon it, of rather more than 10 turns: a standard inch bar is placed in the machine, and adjusted by the gravity piece G in the manner afterwards described, and the position of the centre B is marked by a line against the index H on the first turn of the spiral; and the standard bar being then removed, the centre B is advanced by the screw through the interval of 1 inch left vacant by its removal, and the position again marked by a line on the last turn of the spiral. The spiral is then carefully divided between these two marks into 10 equal parts, each of which is one revolution of the handwheel nearly, and corresponds exactly to ·1 or 1-10th of an inch motion of the centre B; each revolution of the spiral is then subdivided between the divisions previously obtained into 100 equal parts, as shown half full size in Fig. 3, so that each interval on the circumference of the handwheel represents accurately ·001. or 1-1000th of an inch motion of the centre B. By this plan the difficulty and expense of obtaining a screw having exactly 10 threads per inch are obviated in a simple manner, any small excess or deficiency in the pitch of the screw D being thrown into the spiral line on the handwheel, the correct graduation of which is accurately obtained from one of the standard

inch gauges. In order to prevent any play in the nut E it is made in two lengths, which are let together on the screw D, as shown in the section, Fig. 5. The back centre C, Figs. 4 and 5, is merely held tight by friction, by the grip of the wrought iron strap cottered to the bed A ; so that in case the handwheel F should be turned round too far, the back centre will give way and prevent the measuring screw D from being injured by a strain : it is fitted with a small screw I, for the purpose of approximately adjusting the length of the groove in the bed.

The gravity piece G, by which the contact is ascertained by touch in this mode of end or contact measurement, is shown in Figs. 2, 5, and 6. For making a duplicate of any standard gauge by the measuring machine, the standard gauge is laid in the groove of the bed, as shown at K, Fig. 2, and the distance to the back centre C is made up with bars of convenient length, as shown in the complete side elevation, Fig. 1. The measuring screw D and centre B are then advanced gradually by the handwheel F, until the gravity piece G, on being lifted by the finger at one end, as shown dotted in Fig. 6, remains just held up between the ends of the standard gauge K and centre B, and is prevented from falling clear between them, the pressure being just exactly sufficient to support its weight; and the corresponding graduation on the handwheel having been noted against the index H, the centre B is slacked back and the standard gauge removed. The proposed duplicate is then placed in the machine and tried by means of the gravity piece ; and its length is very carefully reduced by grinding the ends, with successive trials in the machine, until the gravity piece is again just supported between the duplicate gauge and the centre B with the same reading on the handwheel as previously, when the length of the duplicate is known to be accurately the same as that of the original standard. The graduation on the handwheel affords the means also of producing gauges differing by any required amount from the standard gauges. Thus the gauges previously described for boring the wheel bosses of 5·995 inches diameter are made from the standard gauge of 6 inches length by subtracting 5 divisions from the reading on the handwheel, so that the measuring screw has to be advanced ·005 or 5-1000ths of an inch further before the gravity piece is held suspended.

The standard gauges used in the machine are steel bars 1 inch square, with the edges bevilled off; the ends are made conical and reduced to a circle of $\frac{1}{4}$ inch diameter, as shown half full size in Fig. 7. A single 1 inch standard is sufficient for producing by the machine all the longer standards that are required, by making first another 1 inch standard, then a 2 inch standard from these two placed together end to end, and so on in succession; and the machine is long enough for measuring any length up to 100 inches, as shown in Fig. 1.

Mr. FERNIE described the process he had followed for obtaining the means of accurate contact measurement on the decimal system; having first procured from Mr. Whitworth a standard 1 inch measure, from which another 1 inch piece was made, and from these combined a 2 inch measure, and so on up to a bar 20 inches long. The measurement was done by contact with a gravity piece on Mr. Whitworth's plan, and all the finer measurements required in the workshop were got in this manner by the machine described in the paper and shown at the conversazione on the previous evening.

In applying the decimal system of measurement to the fitting of wheels on axles, he had tried the largest and smallest differences of size that existed between the diameter of the axle and that of the hole in the wheel nave; and by measuring before the wheel was pressed on and after it was drawn off again, he found that when the hole in the wheel nave was ·012 inch smaller in diameter than the axle, on a diameter of 6 inches, a permanent set of ·006 inch was produced, the hole being permanently enlarged to that extent; and there continued to be a certain amount of permanent set until the allowance of difference in diameter was reduced to ·003 inch, when no set took place. This difference was however rather too fine for working to, and therefore ·005 inch was adopted instead, which ensured the wheel being a thoroughly tight fit on the axle, while it caused only a slight permanent set. For carrying out this plan in practice, standard end

measures were first made, having this difference of ·005 inch in length; from which a pair of inside and outside gauges were made, the former being simply a straight bar for gauging inside the wheel nave, and the latter a calliper gauge of a strong form which was allowed to drop over the axle by its own weight. It was important that the boring and turning should be very smoothly done, and finished with a rather broad tool; otherwise with a pointed tool the surfaces were left rough with threads on them, which were abraded in pressing the wheel on; but if smooth, the surfaces were not injured in pressing the wheel on and less pressure was required.

Mr. C. W. Siemens said it was highly gratifying to see that such great accuracy had been carried out in work on a large scale, and he was confident it would well repay any extra trouble by the superior quality of work obtained and the facility for renewal. Mr. Whitworth had rendered most important service by introducing the system of accurate decimal measurement; but he did not think the inch adopted by him as the unit of measurement was the most eligible, and it might become necessary at a future time to go over the question again in order to adopt a universal standard amongst civilised countries. It was a general opinion of the International Decimal Association that the only chance of getting a universal measure was to adopt the metre, which was convenient for use in this country, being nearly the length of the present yard; while the millimetre was generally the smallest size wanted for the workshop, being 1-26th of an inch (·039 inch). The metre was now becoming the unit in many tables and calculations, and he regretted that another unit should be established in this country. He doubted whether 1-1000th of an inch could be worked to in practice, and thought the gauges employed would be affected to that amount by difference in temperature.

Mr. C. Markham observed that the inch had been adopted as the standard not on account of any intrinsic superiority over the metre, but because it was not practicable to carry out the metre system in this country, and the metre had lately been found to be a scientific fallacy as regarded its supposed perfection as a standard: Mr. Whitworth had adopted the inch as the standard on account of its universal application in the workshops and in all mechanical operations

in this country. There did not appear to be any probability of getting the decimal system of measurement into use in this country except by adopting for the standard the inch already recognised and in general use, so that the introduction of the decimal subdivision involved no change of measure. The improvements that had taken place in the construction of machines and the remarkable truth and accuracy with which work was now executed rendered it essential for the progress of mechanical science that 1-1000th of an inch should be readily appreciated in the workshops by ordinary workmen. The Whitworth and Enfield rifles were bored out to 1-1000th of an inch, and workmen soon became accustomed to work with extreme accuracy and truth. With the decimal system much greater accuracy was obtained than with ordinary fractions, by employing the sense of touch on Mr. Whitworth's plan of end or contact measurement, by which smaller dimensions than 1-000th of an inch were readily appreciated; and in practice it was required to have the means of expressing dimensions down to 1-000th of an inch, as illustrated by the results given in the paper just read. Different descriptions of wheels required to be bored out with slightly different allowances in the diameters, a solid cast iron wheel requiring to be bored out larger than a wheel with a light boss and spokes; and this difference could be readily measured and worked to by the decimal system with the use of gauges in the manner that had been described.

Mr. C. W. Siemens thought the adoption of a universal standard of measurment was so important an object to be aimed at that it ought to be made a chief consideration. The metre was gradually becoming the universal standard on the continent, and was already in considerable use in this country : at Messrs. Sharp's works he believed it was used to a large extent, and also in other mechanical workshops where small dimensions had to be worked to.

Mr. J. Barber said he was engaged at Messrs. Sharp's works, and the metre had been used there for French and Spanish work and for some Russian locomotives made for a French company, in which the dimensions were all marked in metres; and it was consequently more convenient to work with metre rules than to translate all the dimensions into English measures. Giffard's injectors also, being a

French invention, were all made to metre dimensions, and an internal gauge was used consisting of a round steel template tapering 1 millimetre in diameter in every 25 millimetres or about 1 inch of length; this was divided into inches and tenths, enabling the men to work to 1-10th of a millimetre or 1-250th of an inch. The inch was used for all other work, the metre being never employed for English work; and the decimal subdivision of the inch was of great convenience for many purposes.

Mr. T. Dunn did not see how it would be practicable to work to so fine a dimension as 1-1000th of an inch, on account of the alteration of size caused by expansion in a metallic gauge from the variation of temperature to which it was exposed.

Mr. Fernie thought the adoption of the inch as the standard of decimal measurement had been the best step that could be taken, and was the only practical way of introducing the system in this country. He only regretted that mechanical engineers had not taken up the matter more energetically; for there was no difficulty in getting the work done with precision by the decimal system, and 1-1000th of an inch was easily worked to; but by the ordinary mode of measurement no two pieces of work were ever alike. No difficulty had been experienced from change of temperature in working to 1-1000th of an inch; for 1° Fahr. expanded steel 1-150,000th lineally, so that it would take 150° heating to expand a 1 inch gauge 1-1000th of an inch; but the heat imparted to a gauge by being held in the hand at only a part of its surface must be very small in amount. It was an important change in railway work to have the diameters of wheels and axles so accurately determined as to be able to make them on stock, so that they would fit one another indiscriminately and allow of changing at any time for repairs. But in the ordinary mode of work so much difference of diameter was allowed, that after a wheel had once been drawn off the hole was permanently enlarged and the axle reduced to such an extent that each required a different size to be allowed when used again, causing a great accumulation of varieties in dimension; and the ordinary mode of measurement was so imperfect that old wheels and axles were frequently found bored and turned with one end as much as ·005 inch larger in diameter than the other.

Mr. J. Cochrane observed that in the drilling machine he had previously described, which had to drill holes with ·005 inch difference of pitch in the top and bottom plates of the girder, the centres of the drill spindles were set out with great accuracy in the machine, by means of a Whitworth screw of 3 inches pitch, acting on a sliding table; the screw was provided with a wheel with 60 teeth, driven by a worm, one revolution of which moved the wheel one tooth, and a face plate on the worm was divided into 100 parts; thus half 1-1000th of an inch was readily measured. Such a mode of measurement was quite accurate for the finest dimensions required in practice.

Mr. Fernie showed Cocker's decimal measuring instrument which was used in the Midland Railway workshops for small dimensions; the dimensions were taken by callipers from the instrument by the plan of end or contact measure, and they could readily measure with it to 1-1000th of an inch. By gauges for touch or end measure there was no difficulty in working to 1-1000th of an inch, just as in the wire-gauge, where the differences between the Nos. were as small as 1-1000th of an inch, the actual dimension of each No. being expressed in thousandths of an inch in the new decimal wire-gauge.

Mr. J. Barber asked whether the outside template for turning the axles to was not affected by expansion from change of temperature; he thought the form of template might be improved, and the thickness of metal should be uniform throughout, in order to give it sufficient rigidity.

Mr. Fernie replied that the templates must be of a practically convenient form, and were made strong enough for general use in the shop. A corresponding end measure gauge was made for each size of template, and preserved as a standard for reference by which the shop templates were verified from time to time.

The Chairman proposed a vote of thanks to Mr. Fernie for his paper, which was passed.

The following paper was then read :—

DESCRIPTION OF MACHINERY FOR CRUSHING STONE FOR MACADAMISING ROADS.

By Mr. CHARLES G. MOUNTAIN, of Birmingham.

The employment of machinery for breaking stone for macadamising roads has occupied attention at different times; and the writer believes that the late Mr. George Stephenson tried some experiments at the Groby granite quarry near Leicester, but they were discontinued, principally owing to the great wear and tear of the machinery and the uncertainty of production; the machine forming the subject of the present paper is believed by the writer to be the only instance which has proved commercially successful.

The Markfield granite quarries near Ashby-de-la-Zouch in Leicestershire have long yielded a supply of paving blocks for London and other places; and in the process of shaping these blocks, portions called "sledgings" are produced, which are of little value unless reduced into pieces varying from 2 to 2½ inches cube, called respectively "ring-small" and "broken." These were formerly made by breaking the sledgings by hand in a ring or on the ground, which on account of the hardness of the stone was a very tedious and costly operation, as a small quantity only can be produced; the wages paid varied from 2*s*. to 2*s*. 6*d*. per ton, and at times there was great difficulty in obtaining men and boys to perform the work. The firm for whom the machinery now described was made, Messrs. Ellis and Everard of Leicester, having also found that the stone in Bardon Hill near Ashby was eminently suited for macadamising, made arrangements for opening a quarry there in addition to the one at Markfield; and as the demand for the stone was considerable, it became necessary to devise some means for reducing it in large quantities and at a less cost than by hand. A design was therefore prepared, and a machine constructed by the writer by way of experiment; but in the absence of precedent so far as was

known, it was necessary to proceed carefully both in a mechanical and pecuniary point of view, and hence the somewhat rude and simple construction of the machine. A series of experiments were made with the machine, which fully demonstrated the practicability of the operation mechanically, and subsequent experience has proved it to be successful commercially.

The machine used for the experiments was nearly similar to that shown in Figs. 3 to 6, Plates 51 and 52. The driving pinion A, Fig. 6, gearing into the pinions of the crushing rolls, was driven by a spur wheel on the same shaft gearing into a pinion on the crank shaft of the steam engine. The roll spindles BC, Fig. 3, were of wrought iron, hexagonal in the body, one end of each being shaped similar to the wobbler end of the rolls in a rolling mill, as shown in Figs. 4 and 5: the other end had a square thread and nut for securing the crushing rolls, the thread being left-handed on the spindle B in each pair of rolls and right-handed on the other spindle C. The roll pinions were connected to the roll spindles by ordinary coupling boxes and break spindles D. The roll spindles BC revolved in chilled cast iron bearings, those of the spindles B being stationary in the frame of the machine, while the bearings C were moveable in a horizontal slot and held up by the levers E, the required pressure being obtained by weights suspended from the ends of the long levers F. A wrought iron hopper G was fixed on the top of the machine, into which in the experiments the stone was thrown by hand; after passing through the upper rolls it fell roughly broken upon the feed plate H of the lower rolls, which was hung on a centre at the back, while its front edge protected by a strip of steel rested on one of the lower rolls, which gave it a shaking motion serving as a feed to them. The mill was temporarily fixed on a wooden frame, and was driven by a horizontal high pressure steam engine with a cylinder of 10 inches diameter and 20 inches stroke, making 70 revolutions per minute and working with a pressure of 50 lbs. per square inch, the steam being cut off by an ordinary slide valve at three fourths of the stroke. The pinion on the crank shaft was 10 inches diameter, and the spur wheel on the mill shaft 70 inches, giving a speed of 10 revolutions per minute to the rolls. A number of experiments were tried to

determine the best speed, and the final result has been the adoption of 15 revolutions per minute in the present working of the mill, as the most satisfactory speed for the rolls.

In order to determine the proper form of the crushing rolls, experiments were made with different forms of rolls, in the first of which they were formed with alternate plain and toothed discs, as shown in Figs. 8 and 9, Plate 53. In the upper rolls, Fig. 8, the pitch of the teeth was 8 inches, and $4\frac{3}{4}$ inches pitch in the lower, Fig. 9. The diameters were such that the teeth of one roll ran into the spaces formed by the plain discs of the other, the object being to crack the pieces of stone without pulverising them. In this experiment the teeth of the rolls were arranged in a line in all the discs. The result was that much gravel was produced and some very irregular shaped pieces of stone. In the second experiment the top rolls were formed of discs similar to those tried in the previous experiment and shown in Fig. 8; but they were of smaller diameter, and the teeth were arranged in a spiral, by advancing each succeeding disc that was put on the spindle one sixth of a revolution. The bottom rolls were made as shown in Fig. 10, the discs being alternately plain and toothed. The object of trying this form of teeth was to determine how far a shearing motion would be effective. The results proved that the upper rolls were more effective than those in the first experiment, while the lower rolls, Fig. 10, were choked and broken by the pieces of stone getting jammed in between the teeth, which necessitated stopping the mill to remove them. The stones produced were very irregular in size, and also a large quantity of gravel was made. In the third experiment the upper rolls were made with a series of toothed discs of the form shown in Fig. 11, the teeth being $5\frac{1}{2}$ inches pitch and arranged spirally in the manner before described. The lower rolls were made with discs of the form shown in Fig. 12, with the teeth arranged spirally. With these rolls the stones produced were of a more uniform size than before, but still with a large quantity of gravel. In the fourth experiment the same upper rolls were used, Fig. 11; but the lower were made with discs of the form shown in Fig. 13, arranged spirally. The result was that stones of more regular

shape were produced, but still with much gravel. In the fifth experiment the same upper rolls were again used, Fig. 11; but the lower rolls were made with discs shaped as shown in Figs. 14 and 15, and the centres were so arranged that the circumferences would just clear each other. This experiment gave a very good result, the quantity of gravel being much diminished, while the stones produced were more regular and uniform than in any previous trial: the strain on the machine was much more uniform, and the engine worked very satisfactorily. In the sixth experiment the upper rolls, Fig. 11, and lower rolls, Fig. 14, were made of discs similar in form to those tried in the fifth experiment, but two were cast together, with the teeth alternating so as to give greater strength. In the rolls now used, as shown in Figs. 3, 4, and 5, Plates 51 and 52, the discs are cast in pairs in the same manner, and the teeth of every alternate disc are in line, so that there is no occasion for setting the discs spirally on the spindles; and to avoid the necessity of a second pattern for the upper rolls, the lower rolls are made to serve as upper rolls when they have become too much worn for crushing the stone down to the required size. The rolls tried in the experiments were made from South Staffordshire cold-blast iron, and moulded in the usual way, and of course were moderately soft; but the experiments clearly showed that a harder material was necessary, and arrangements were therefore made for chilling them internally and externally.

The quantity of stone crushed varied in each experiment, and as the machine was fixed only temporarily it was not possible to arrive at a very definite result; but the average was at the rate of 6 tons per hour. In all the experiments the engine did its work well, except at times when the stone was unduly fed, when it was brought to a stand. In place of the feeding plate H of the lower rolls, a frame with bars rivetted longitudinally was tried, suspended and worked in the same manner; but it was found that wedge-shaped pieces of stone got jammed in and prevented its action.

The result of these preliminary experiments was so far satisfactory that it was decided to complete the machine by putting a feed motion and other gearing to it; and also to erect a building to contain two

machines with the necessary machinery for driving them. The general arrangement of the mill and machinery is shown in Figs. 1 and 2, Plates 49 and 50; Fig. 1 being a half plan, and Fig. 2 a longitudinal section of the building. There are two egg-ended boilers I, 24 feet long and 5 feet diameter, which supply steam to a horizontal engine J with a cylinder of 20 inches diameter and 42 inches stroke, making 35 revolutions per minute. The pinion K on the crank shaft with 44 teeth of 3 inches pitch gears into the spur wheel L of 105 teeth, which drives the crushing mill B through the pinion A, Fig. 6, Plate 52, the rolls thus making 15 revolutions per minute. The upper longitudinal shaft M, Fig. 2, is driven from the crank shaft by two pairs of mitre wheels and an upright shaft; it drives by bands the feed gear of the crushing machines, and by pinions the elevators N. The circular riddles O are driven from the end of the shaft M.

The crushing mill previously described was first fixed in the building with its feed apron, elevator, and riddle. The feed apron P, Figs. 1 and 3, Plates 49 and 51, as first constructed consisted of alternate side links, crossbars, and flat links, which were secured together by rivetting over the ends of the bars, forming a continuous perforated apron. The outer end of the apron is extended from the side of the building and supported by brackets or arms hinged on a centre, and these are slung by chains with friction clamps so that the whole or any part of the weight of the arms can be allowed to act for extending the apron. Side cheeks of wrought iron are placed on each side of the apron, extending from outside the building to the feed apparatus at the mill. The feed apparatus is driven by a band from the upper longitudinal shaft M, Fig. 2, passing over the pulley Q, Figs. 3 and 5; it consists of the two octagonal driving bosses R, Figs. 5 and 7, on which are fixed steel lugs, placed so as to catch the crossbars of the feed apron. For levelling the stone on the feed apron the shaft S is placed above the apron, having six wrought iron dispersers with five curved fingers on each; these are driven in a contrary direction to the apron and at a greater speed, so that any unusual quantity of stone is thrown back and the hopper G is prevented from being choked. The amount of opening allowed for the passage of stone between the dispersers and the feed apron can be varied by adjusting the radial arms carrying the shaft S.

The elevator N, Figs. 1 and 2, consists of a chain similar to the feed apron, but without the flat links, carrying the buckets, which were made of wrought iron with malleable cast iron ends rivetted on, and were attached to the chain by T headed bolts with the nuts inside the buckets. The elevator is driven by octagonal bosses in the same manner as the feed apron. The lower end is fixed below the floor line, as shown in Fig 2, the bottom shaft running in two gun-metal bearings in standards which are provided with means of adjustment to allow for the wear of the chains. The broken stone is led from the crushing mill B to the bottom of the elevator by the wrought iron spout T.

The riddle O, Figs. 1 and 2, is made of T iron rings with five longitudinal stays, and is divided into two lengths, which are covered on the outside with $\frac{3}{8}$ inch round bars. As the distance between the bars was matter of experiment, they were made loose so that they could be adjusted to any space, and were held by two clamps to each compartment of the riddle; the two compartments are spaced differently for the purpose of delivering two sizes of gravel. When the proper distance was determined, the bars were secured by wooden wedges driven tightly in. The riddle was driven from the outside of the T iron rings by four friction wheels, which were attached to inclined shafts driven by gearing from the longitudinal shaft M.

The mill upon completion and trial worked much more satisfactorily than at the time of the first experiments; but the speed of the elevator N, 180 feet per minute, was found to be too great, and after a number of trials the present speed of 90 feet per minute was adopted. The elevator buckets also did not take up their full quantity of stone, but some of the pieces passed between them and through the chain. The chain was therefore covered with sheet iron $\frac{3}{16}$ inch thick; and a cast iron pan was fixed at the bottom of the elevator, mounted on a bedplate which admitted of adjustment vertically and longitudinally. The pan was shaped so that the buckets would just rub the mouth; but it was found absolutely necessary to allow room for the motion of the chain at the back, and after some trials 6 inches clearance was allowed from the line of the chain when tight. A pair of bevil wheels for driving the elevator were fixed, and a friction clutch was added to prevent breakage. The speed of the riddle O was also reduced to 16 revolutions per minute.

The results obtained were so far satisfactory as to induce the fixing of a second crushing mill and gearing. In this, arrangements were made to facilitate the removal of the rolls; a crane was erected for the purpose of changing them, and other simple appliances were added for facilitating the operations of the mill. The long counterbalance levers F, Fig. 3, and weights were dispensed with, and an elastic packing of vulcanised india-rubber was substituted, placed at the back of the sliding bearings of the rolls, with adjusting screws to give the required resistance. Gun-metal bearings for the roll spindles were substituted for chilled iron. The feed apron P was strengthened, and the hopper G altered so as to confine the pieces of stone which before were liable to fly about. A stronger chain was made for the elevator N, the buckets of which were made more taper, to allow for the more ready delivery of the stone. The riddle O was also lengthened, as shown in Figs. 1 and 2, and a spiral end attached for the purpose of separating the stone, those pieces which are of the approved size passing through the meshes and by a spout into the wagon, while those which are two large pass out at the end, and by another spout on to a stage, whence they are barrowed back again into the mill and thrown into the lower rolls. The gravel is divided into two sizes, delivered through the two compartments of the upper end of the riddle.

Upon both mills being tried together, the engine worked more pleasantly, as one appeared to regulate the other. Subsequent experience proved that the wear of the elevator buckets was very great, and they have therefore been made with steel strips rivetted to the front, and the elevators are guided by wooden rollers: also that the bolts attaching the buckets to the chain were not sufficiently secure, in consequence of the heads projecting on the inside of the chain; and this has been remedied by making the intermediate links of the chain solid to which the buckets are attached, and drilling the bolt holes, the bolts being made with countersunk heads so that they are quite flush with the underside of the links. The mode of driving the riddles has been altered by extending the longitudinal shaft M, on which are fixed two shrouded pulleys, driving the riddles by bands, as shown in Figs. 1 and 2; the speed has also been reduced to 8 revolutions

per minute. The riddles are now carried by shafts passing through the centre, which are secured in three wrought iron crosses bolted to the T iron rings; the shafts run in bearings which are supported by cast iron carriages resting on the timber framework, as shown. The spaces between the bars of the riddles have been permanently fixed at $\frac{3}{8}$ inch and $\frac{5}{8}$ inch, and the meshes at the lower ends have been fixed at $2\frac{1}{4}$ inches square, which is the size of the stone required. In every important respect the machinery remains as it was started: but the working has clearly shown that the crushing mill first erected performs its work most satisfactorily, as the wear and tear are less, the counterbalance levers appearing to relieve the mill in case of undue strain more efficiently than the india-rubber packing; this mill also produces better and more regular shaped pieces of stone.

The machinery has now been started about two years, and works in a most satisfactory manner, with almost as much regularity as any other machinery, notwithstanding the rough usage it has to encounter. The wear and tear are considerably less than at first anticipated, one smith and striker being able to keep the whole in good repair. The chilled rolls which were considered most important have been so far perfected that one pair, weighing $10\frac{1}{2}$ cwts. each roll, will last in constant wear for about 21 days as lower rolls: these are then used as upper rolls, while the upper ones that are removed are returned to recast. Each pair of new rolls thus produces about 1800 tons of stone. Specimens of the rolls are exhibited, showing the new roll and one after its removal for renewal: a broken specimen is also shown, to exhibit the grain of the iron and the amount of chilling. Specimens of the stones are also shown, together with samples of the gravel and dust; and it is worthy of remark that this dust answers in most cases for all the purposes to which emery is applied in engineers' shops, and if very fine is almost equal to Turkey dust.

The production of finished stone varies from 60 to 80 tons per day of 10 hours, for each mill, including stoppages. The relative quantities of finished stone, gravel, and dust produced per ton of stone are as follows:—

Finished Stone	15 cwts.	or	75·0 per cent.
Coarse Gravel	3 ,,		15·0 ,,
Fine Gravel	$1\frac{3}{4}$,,		8·8 ,,
Dust	$\frac{1}{8}$,,		0·6 ,,
Waste	$\frac{1}{8}$,,		0·6 ,,
	20 cwts.		100·0

The consumption of coal for driving one mill and gearing is about 24 cwts. per day of Whitwick slack, and for two mills and gearing 35 cwts. per day. The number of men required to work the whole of the machinery is eight: one engine driver, who also attends the boilers; two men to each mill to feed; one man to each mill to attend the riddles, and the shunting and moving of the trucks; and one boy inside to attend the two mills. There are two bells and a steam whistle to call attention, as the noise is so great that the voice can scarcely be heard inside the mill.

The accompanying indicator diagrams, Figs. 16 to 18, Plate 54, show the power required to work the mills and gearing. The engine from which they are taken was not designed for the special purpose of the mill, and was not attempted to be made more than an ordinary commercial engine. The diagrams shown in Fig. 16 were taken in February 1859, after the engine had been working five months. The diagram shown by the full line was taken while both mills were being fed by three men each, as uniformly as possible, each mill delivering at the rate of 14 tons of riddled stone per hour: the engine at the time was making 35 to 30 revolutions per minute, and the pressure was 50 lbs. per square inch in the boilers. The diagram shown by the dotted line was taken while the mills were being fed with very irregular pieces of stone in a careless manner by two men to each mill, so as to show the probable variation in feed and in power required: the pressure at the boilers fell during the alteration, and was only 30 lbs. when the indication was taken. In both these cases the expansion gear was arranged to cut off the steam at one third of the stroke. The shaded diagram was taken to show the power required to drive the machinery alone, the pressure at the boilers being 10 lbs., and the expansion gear being thrown out. The mean pressure in the diagram shown by the

full line is 29·6 lbs. per square inch, giving 74 horse power as the power produced. The mean pressure in the diagram shown by the dotted line is 17·8 lbs. per square inch, giving 44 horse power as the power produced. The mean pressure in the shaded diagram is 4·4 lbs. per square inch, giving 11 horse power as the friction of engine and machinery. The speed of the engine varied between 35 and 40 revolutions per minute during the experiments, and is taken at 37½ revolutions per minute in calculating the horse power. The consumption of coal being 35 cwts. or 3920 lbs. per day of 10 hours is therefore by the full line diagram equal to 5·3 lbs. per indicated horse power per hour, and by the other diagram 8·8 lbs. : a mean between which is 7·1 lbs. per indicated horse power per hour.

The diagrams in Fig. 17, Plate 54, were taken on 30th July last, for the purpose of showing the irregularity in the power required, one mill only being driven, which was fed with very irregular sized pieces of stone. The pressure in the boilers was 48 lbs., and the expansion gear was set to cut off at one third of the stroke. The mean pressure in the diagram shown by the full line is 20·5 lbs. per square inch, while in the diagram shown by the dotted line it is only 12·8 lbs. per square inch. This gives as the power represented by the full diagram 51 horse power, and by the dotted line 32 horse power; and a mean between these gives a consumption of 6·5 lbs. of coal per indicated horse power per hour, taking the actual consumption per day of 10 hours as 24 cwts. or 2688 lbs. when driving one mill only. The shaded diagram was taken to show the power required to drive one mill and gearing empty; the pressure in the boilers being 27 lbs., the mean pressure indicated is 2·5 lbs. per square inch, which gives 6 horse power as the power required to drive one mill and its gearing.

The diagram in Fig. 18, Plate 54, were taken to show the greatest variation noticed in the power required and given out by the engine while driving one mill in regular work. The two full lines are with heavy work on the mill, and the two dotted lines with light work. The pressure in the boilers was kept at 27 lbs. per square inch, and the expansion gear was set to cut off at one third of the stroke. The full diagrams show a mean pressure of 15·1 and 10·2 lbs. per square inch, giving 38 and 25 horse power respectively: great care

was taken to feed regularly, and the mill produced the broken stone at the rate of 11 tons per hour. The dotted diagrams give a mean pressure of 4·7 and 3·5 lbs. per square inch, representing 12 and 9 horse power respectively. The coal consumed was Whitwick slack, the cheapest coal that could be obtained.

From the experience with the present mill it would appear that, in case of any more machinery being erected for the same purpose, the most effective and economical plan would be to attach a separate steam engine to each mill and gearing, running at a quick speed with a heavy counter-flywheel. The writer is indebted to Messrs. Ellis and Everard for placing the mill at his disposal for making the experiments, and for their concurrence in the preparation of the present paper.

Mr. Mountain showed samples of the pieces of stone as supplied to the machine from the quarry, the broken stone produced, and the gravel and dust: also specimens of new and worn out crushing rolls. He explained that the object of the machinery was to produce equal sized pieces of stone for macadamising, with the least waste possible.

Mr. T. Dunn asked what iron the rolls were made of, and how they were chilled so deeply.

Mr. Mountain replied that the rolls were made of best South Staffordshire cold-blast iron, chilled in cast iron moulds. None but the hardest material would stand the work, but these rolls stood about two months before they were put aside as worn out.

Mr. W. Richardson thought it would have been better to dispense with the feeding apron for lifting stone up to the crushing machine, and to fix the machine so that the stone should be delivered into it by a shoot without requiring lifting.

Mr. Mountain said it was originally intended to fix the machine at the quarry where the stone could be delivered direct into the hopper; but the special circumstances of the case prevented that arrangement being carried out, and required the employment of the

apron to feed the machine. In another case of erecting such machinery the elevator also would be dispensed with, and it had indeed proved one of the greatest difficulties to get it to work well.

Mr. F. Wrigley asked what was the cost of the machine, exclusive of buildings.

Mr. Mountain replied that the cost of the two machines alone was about £3000; and the total cost in the present case, including the buildings and engine and preliminary experiments, had been about £7500.

Mr. J. Fernie asked whether the axles of the crushing rolls were hardened, and what bearings they ran in; also what was the cost of chilling the rolls.

Mr. Mountain replied that the axles were not casehardened, but were simply the turned ends of the wrought iron hexagonal shafts on which the rolls were fixed; these stood very well, running in brass bearings. In the first trials the carriages of the roll shafts got broken when hard pieces of stone came between the rolls; but the bearings were now held up by the weighted lever, which allowed the rolls to yield in the event of a piece of stone too hard to be broken getting jammed in the machine. The cost of chilling the rolls was merely that of the extra moulder's time and of the chilling moulds, probably about 50*s.* per ton additional upon the cost of the castings. The separate plates of the rolls were simply threaded loose on the hexagonal shafts; but the effect of working was to tighten them on the shafts, on account of the nuts on the shafts being made either right or left-handed screws according to the direction of rotation, so that any motion of the plates would tighten the nuts.

Mr. E. A. Cowper enquired what was the cost of renewing the crushing rolls per ton of stone crushed.

Mr. Mountain said the cost of the rolls was about 1½*d.* per ton of stone crushed.

Mr. F. Wrigley asked what was the cost of the crushed stone delivered at the works.

Mr. Mountain did not know the exact particulars of the cost, having been concerned only in the construction of the machinery; but the cost of breaking stone by hand was about 2*s.* 6*d.* per ton, and

they had aimed at crushing it by the machine at less than 10*d.* per ton, which he believed had been successfully accomplished.

The CHAIRMAN thought the machine was very well contrived, and appeared to accomplish the work successfully and with less dust than had been made in previous attempts. He remembered a machine being tried at Bury many years ago for the same object, made by Mr. Routledge; but after working for about twelve months it was abandoned, on account of its crushing to dust a considerable proportion of the stones broken.

Mr. SAMUEL LLOYD observed that they employed a machine of very small cost at the Old Park Iron Works for crushing the "bull-dog" or calcined cinder for lining the puddling furnaces, which was done by passing it through rollers; the cost was under 2*d.* per ton, but in this case the shape and size of the broken pieces were immaterial.

Mr. MOUNTAIN said the object in the present machine was to get the stone broken into as nearly cubical pieces as possible, not exceeding a certain size, with the least quantity of gravel and dust: this was the great difficulty to be contended with in breaking stone by machinery, and any process in which the stone was too much pulverised would be unsuitable.

The CHAIRMAN moved a vote of thanks to Mr. Mountain for his paper, which was passed.

A special vote of thanks was proposed by Mr. E. A. Cowper, seconded by Mr. C. W. Siemens, and passed, to the Local Committee and the Honorary Local Secretary, Mr. Walter May, for the excellent arrangements they had so kindly made for the meetings and for the conversazione on the previous evening.

The Meeting then terminated, and in the evening a large party of the Members and their friends dined together at the Music Hall.

On the following day an excursion of the Members and their friends took place into the Iron and Coal District of South Staffordshire, by special train to the Soho Engine Works, the Oldbury Carriage Works, and the Bromford Iron Works, where one of the coal pits was descended to see the working of the Ten Yard coal; and thence by special canal boats through the new Netherton Tunnel, about $1\frac{3}{4}$ miles long, recently constructed through the Rowley basalt ridge or great anticlinal axis of the South Staffordshire coalfield. The Woodside Iron Works were then visited, where the drilling machine that had been described at the meeting was seen at work, drilling the plates for the girders of the new Charing Cross railway bridge. The Members next visited the Round Oak Iron Works described at the meeting, where a large collection of specimens of the iron made in the works was exhibited; and thence proceeded to the Dudley Castle Limestone Caverns, which were brilliantly illuminated for the occasion by the kindness of the Earl of Dudley, by whose hospitality also the Members were handsomely entertained at the Round Oak works. The Members returned to Birmingham in the evening by special train.

PROCEEDINGS.

1 November, 1860.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Thursday, 1st November, 1860; Henry Maudslay, Esq., Vice-President, in the Chair.

The Minutes of the last Meeting were read and confirmed.

The Chairman announced that the President, Vice-Presidents, and five members of the Council in rotation, would go out of office in the ensuing year, according to the rules of the Institution; and that at the present meeting the Council and Officers were to be nominated for the election at the Annual Meeting.

The following list of Members was adopted by the meeting for the election at the Annual Meeting:—

PRESIDENT.

Sir William G. Armstrong, . Newcastle-on-Tyne.

VICE-PRESIDENTS.

(*Six of the number to be elected.*)

Alexander B. Cochrane, .	Dudley.
James Fenton, . . .	Low Moor.
Benjamin Fothergill, . .	London.
James Kennedy, . . .	Liverpool.
Sampson Lloyd, . . .	Wednesbury.
William Mathews, . . .	Dudley.
Henry Maudslay, . .	London.
James E. McConnell, .	Wolverton.
John Penn, . . .	London.
John Ramsbottom, . . .	Crewe.
J. Scott Russell, . .	London.
Joseph Whitworth, . .	Manchester.

COUNCIL.

(Five of the number to be elected.)

John Anderson,	Woolwich.
Charles F. Beyer,	Manchester.
Samuel H. Blackwell,	Dudley.
John E. Clift,	Birmingham.
William Henry Dawes,	Westbromwich.
George Harrison,	Birkenhead.
Robert Hawthorn,	Newcastle-on-Tyne.
James Kitson,	Leeds.
Walter May,	Birmingham.
William Weallens,	Newcastle-on-Tyne.

The Chairman announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following New Members were duly elected :—

MEMBERS.

William Fothergill Batho,	Birmingham.
William Phipson Beale,	Rotherham.
Edward Hamer Carbutt,	Derby.
Henry Cochrane,	Middlesborough.
James Cope,	Dudley.
Hiram Craven Coulthard,	Blackburn.
David Cowie,	Abo.
Frederick Groom Grice,	Westbromwich.
Thomas William Lewis,	Merthyr Tydvil.
Joseph Mayer,	Linz.
John Parkin,	Sheffield.
William Weild,	Manchester.
William Wilson,	London.

The Chairman moved in accordance with a recommendation of the Council that the General Meetings be held on Thursdays instead of Wednesdays, understanding it would be more suitable to the Members and cause increased attendance; and the motion was passed.

The following paper was then read :—

ON TAKING OFF THE WASTE GAS FROM OPEN-TOPPED BLAST FURNACES.

By Mr. SAMUEL LLOYD, Jun., of Wednesbury.

The writer having been requested at the last meeting of the Institution to give a description of the plan now adopted at the Old Park Iron Works, Wednesbury, and several other works, for drawing off the combustible Waste Gas from Blast Furnaces without the use of a close top, has collected the following information on the subject. The plan now so successfully in operation was not hit upon at once, but only tried as a kind of last resource, after other modes of taking off the gas had been abandoned on account of being so injurious to the working of the furnace as to be inadmissible.

At the Old Park Iron Works the first attempt to make use of the gas was in 1849. It was thought that if three openings, each about 2 feet square, were made into the furnace about 12 feet below the filling holes, at equal distances round the circumference, and were connected by a brick flue to the boilers, enough gas would issue through them to raise the greater part of the steam required for the blast engine. These holes were accordingly made, opening into the brick flue which was built round the outside of the furnace. Practically however this arrangement did not answer, for it was found impossible to keep the brick flue air-tight; and it had not been long at work before several explosions took place; at last it blew up with a force which seemed almost to shake the whole works, and sent the bricks flying in all directions. To remedy this a wrought iron tube was substituted for the brick flue. This was a great improvement, but still sufficient gas would not come down the tube to be of much service, owing to the blast engine chimney not being powerful enough, as it was only about 90 feet high and about 2 feet 4 inches square inside at the top, for seven boilers, several of which had still to be

fired with slack to supply the blast engine with the required quantity of steam; so that there was but little draught left for the one or two boilers to which the gas was applied.

It was soon found that the holes in the furnace had a tendency to clinker up whenever the furnace was standing, owing to a return current of air setting in through them into the furnace, which occasioned a considerable quantity of mine to set quite hard around and beneath the holes, causing the furnace to slip and work so badly that they had to be filled up again. Instead of these a wrought iron cylinder was introduced into the furnace top, and the end of the wrought iron gas tube leading to the boilers was inserted into the side of the furnace. Only a small portion of the gas however found its way down to the boilers, so that nearly as much flame appeared at the tunnel head as before the insertion of the cylinder.

At the same time an attempt was made to use the gas in one of the hot-air ovens, without making any alteration in the oven itself or its three chimneys, which were only about 6 feet high. A fan was fixed in a cast iron box, from which cast iron pipes 12 inches diameter were carried up outside the furnace, the end pipe entering into the furnace behind the cylinder. A larger pipe was fixed to convey the gas from the fan to the oven. The fan was driven at 900 to 1000 revolutions per minute, which forced a considerable quantity of gas into the oven, the fan shaft being kept cool by being made hollow, with a small stream of water trickling through it. This experiment was not continued any great length of time, in consequence of the fan which was an old one breaking down; but it proved that with a fan of sufficient size it would be quite possible to draw off all the gas given off by a furnace. The writer however recommends as preferable for such a purpose an exhauster on the plan of Lemielle's described in the paper read before the Institution in 1858. This machine is extensively used in Belgium and France for ventilating coal mines, and from its slow motion appears preferable to a fan, which from its quick speed is so likely to get out of order.

The furnace had not been working long with the wrought iron cylinder inserted in the top before the cylinder was burnt off and fell in, owing to the great heat at the furnace top in consequence of so

little of the gas being drawn down to the boilers. It was evident from these experiments that a much more powerful chimney was needed to draw down the gas efficiently. A stack was accordingly erected which is 130 feet high and 6 feet 6 inches diameter inside at the top; and a new cylinder like the previous one was then inserted in the furnace top. This resulted in plenty of gas being drawn down, working very well under the boilers. The furnace however was injuriously affected, the make of iron being lessened and the quality not so good as before, the iron being white with a burden of fuel which ought to have produced grey forge iron. Several alterations were made successively in the plan of taking off the gas, but the furnace was more or less injuriously affected by each, the make of iron being in every case diminished and the quality variable. On several occasions portions of the coke and ironstone that had been put in at the top of the furnace were shovelled out at the bottom very much in the same state as when they were put in. A shorter cylinder and one or two others of different sizes were also tried, but without satisfactory result. The use of the gas was therefore entirely abandoned at the above works.

In 1852 Mr. Blackwell endeavoured to make an economical use of the waste gas at the Bilston New Furnaces, and communicated the results of this attempt to the Institution in a paper read in October of that year. In the first instance the furnace upon which he tried the experiments was blown in with a cylinder inserted at the top; and it was found as at the Old Park Iron Works that constant slipping and fretting tuyeres with all their attendant bad results were the consequence. A close top was therefore tried, closed with a cone that was lowered for charging, and a great improvement in the working of the furnace immediately resulted; yet nothing but white iron was produced. In order if possible to produce grey iron, the burden was lightened two or three times; but although the cinder became exceedingly grey, still the iron was white. It was evident that the white iron was caused by the close top; and as it was important to produce grey iron, it was determined to sacrifice the use of the gas entirely, rather than continue making white iron. The gas was

therefore allowed to escape freely by large openings made in the gas main; when a decided change was at once manifest; the iron became grey and the furnace worked with regularity. The white iron had evidently been caused by the pressure produced by the close top; and the furnace appeared to be so sensitive to the slightest pressure that the writer was informed on visiting the works at the time that even a strong wind blowing into the opening through which the gas was principally escaping was found to throw the furnace back to white iron.

At the Brymbo Iron Works, near Wrexham, the first attempt to use the gas was made in 1849 by the insertion of a cylinder in the furnace top similar to the one already described as tried about the same time at Wednesbury. Though not so injurious to the working of the furnace as when applied at Wednesbury and Bilston, its effect was sufficiently unsatisfactory to cause the loss at the furnace considerably to exceed the saving at the boilers; so that after some months' trial it was taken out of the furnace, and the use of the gas abandoned for some time. A year or two afterwards, about the same time that Mr. Blackwell made the experiment just mentioned, a close top was tried on one of the Coalbrookdale furnaces at Horsehay, made with a cone similar to those that were answering satisfactorily at the Ebbw Vale furnaces in South Wales: but the working of the furnace was so deranged by the close top that it had to be taken out; and no attempt has since been made to economise the waste gas in Shropshire. Soon after this close top was taken out it was removed to Brymbo, where it was tried; but the furnace worked worse than when the cylinder was used. It was therefore taken out again, and no further attempt was made to use the gas there till 1857, when Mr. Charles E. Darby decided to try the plan which forms the subject of the present paper.

This plan consists simply in inserting into the open furnace top a continuation of the descending tube conveying the gas down to the boilers, which reaches down into the centre of the materials to a sufficient depth to secure drawing off the gas without admixture of air.

Fig. 1, Plate 55, shows the general arrangement of the apparatus for taking off the gas from the open-topped furnace at Brymbo, and burning it under the steam boilers of the blowing engine. The

wrought iron tube A for taking off the gas is 3 feet 9 inches diameter outside, and is inserted into the centre of the open top of the furnace which is 9 feet diameter. The descending main B, 3 feet diameter, conveys the gas down the outside of the furnace to the horizontal main C, which passes across the ends of the three steam boilers, one of which is shown in section at D. The gas is delivered by a branch pipe E, 22 inches diameter, into the furnace of each boiler just above the firedoor, where it is burnt by admitting the necessary supply of air through holes in the firedoors and through sliding doors above them when more air is required. The supply of gas is regulated or shut off by a throttle valve in the branch pipe E. The ashpits of the three boilers under which the gas is burnt are closed by iron doors. A small fire is kept on the grates, close to the mouth of the pipe E through which the gas is admitted, as a precaution against its ever entering under the boilers in an unignited state after any temporary stoppage, and then causing an explosion by becoming suddenly ignited. The gas is drawn down from the furnace by the draught of the chimney F, which is about 90 feet high and rises about 40 feet above the level of the furnace top; it is 2 feet square at the top, giving an area of 4 square feet. The draught of this chimney, which is equal at its base to 0·74 to 0·84 inch column of water when the gas is being used, is found to be quite sufficient for drawing off enough gas for two boilers, but scarcely powerful enough to draw down the quantity required for three; for when the three are on, one third more steam is not raised, as would be the case if the chimney were sufficiently powerful, since the furnace makes gas enough for three boilers, a quantity always escaping at the tunnel head even when the three are on. The draught for the fourth boiler, which is worked with a coal fire alone, is supplied from another chimney.

Fig. 6, Plate 58, shows an enlarged vertical section of the end of the gas tube that is inserted into the open top of the furnace. It consists of a wrought iron bend A, made of $\frac{1}{2}$ inch boiler plate, 3 feet in diameter, with a thick cast iron cylinder G attached to it, which is buried in the charge of the furnace, and secured to the wrought iron bend by a rivetted joint. The cast iron cylinder is 3 feet 6 inches long below the joint, and recessed at top to form a flush joint outside;

the metal is $1\frac{3}{8}$ inch thick, and increased to 2 inches thick at the bottom edge. The bend and cylinder are supported in their position by a centre bolt from a cross girder resting on the tunnel head; and the bend is bolted by an angle iron flange to the end of the gas main, which passes out in the space between two of the ordinary filling holes, four in number, which are thus not interfered with. The bottom of the gas tube is 5 feet below the level of the filling plates; and the materials in the furnace are filled up to the top of the cast iron cylinder G, and should be kept at that level so as to ensure the end of the tube being always sufficiently covered in the furnace to prevent air being drawn in with the gas. A wrought iron hinged door H, Fig. 1, of about 3 square feet area, with a 56 lbs. weight upon it to keep it closed, is provided upon the upper part of the gas main, opening outwards, to act as a safety valve in case of any accidental explosion.

The first tube inserted into the furnace in 1857 was made as an experimental one of old wrought iron plates, and lasted only about two months. It was replaced by a stronger one made of $\frac{1}{2}$ inch plates; but as this lasted only about five months and the next one made of the same strength lasted only about the same time, it was decided to make the part which descends into the materials of the furnace of cast iron, because when made of wrought iron it had a tendency to collapse under the pressure of the surrounding materials whenever it became hotter than usual. Two of these cast iron ends have now been used, as shown in Fig. 6, Plate 58, lasting about eleven months each, and satisfactorily resisting the heat and compression to which they are subjected, without requiring any repair or attention during that time. When the cylinder requires to be replaced in consequence of the bottom burning away, the whole bend is detached and lifted out, and a fresh one fixed in its place; and so little work is required to make this change that the whole delay caused to the furnace was only about 3 hours the last time the cylinder was renewed. The plates of the descending gas main B, Fig. 1, Plate 55, are only $\frac{1}{8}$ inch thick, and though the apparatus has been erected ten years are still in good order; a greater thickness however is desirable, to provide against waste from oxidation.

In consequence of the success attending the new arrangement for using the gas at Brymbo, the writer recommended its adoption at the Old Park Iron Works, and it was decided to alter accordingly the apparatus previously tried there.

Fig. 2, Plate 56, shows the apparatus as now at work at the Old Park Iron Works. The wrought iron gas tube A is 4 feet 6 inches diameter inside at the bottom and 4 feet 9 inches at the upper part, and is made of $\frac{1}{2}$ inch boiler plate; it has a cast iron cylinder G, 4 feet 6 inches diameter, rivetted to the bottom, 2 inches thick at the lower edge and 3 feet 6 inches in length, as shown enlarged in Fig. 7, Plate 58, extending 6 feet below the level of the filling plates. The tube A is carried by two cast iron girders I I fixed across the tunnel head; and the branch tube K is carried out of it at a height sufficient to allow of the workmen passing underneath, so that the ordinary filling holes of the furnace are not interfered with. The branch tube K is carried by a cast iron saddle upon the girder I, as shown in Fig. 3, Plate 56, which serves to protect the underside of the tube from being injured by the flame of the furnace. The descending gas main B is flat bottomed, 4 feet 3 inches wide by 4 feet 6 inches high, and inclines gradually downwards to the steam boilers of the blast engine, which are at a distance of about 200 feet from the furnaces. Two safety valves H H are provided on the gas main as a provision against any explosion.

One of the boilers is shown in section at D, and the gas is supplied to each by a rectangular tube E, of 4 square feet area, brought down from the horizontal main C which extends along the end of the boilers; the supply of gas to each boiler being regulated by a flat slide valve, as shown in the drawing, at the top of the tube E. The gas is admitted to the furnace over the firedoor and thrown against an inclined brick arch, which deflects it downwards to mix with the air entering at the firedoor. The boiler has two flues and is fired underneath, the flame passing underneath to the back, returning through the flues and back on each side to the chimney F, which is 130 feet high and extends 85 feet above the level of the materials in the furnace. The ashpit is bricked up, but a small fire is kept under each of the boilers close to the firedoor, as a precaution against the

gas ever passing under the boiler unignited. There are six boilers heated by the gas from the one furnace ; these with two others supply the steam for the engine blowing three furnaces, a refinery, two cupolas, and about thirty smiths' fires.

In the first application of the gas apparatus to this furnace, it was thought desirable to protect the cast iron cylinder G in the furnace top by a casing of firebrick, and it was therefore constructed as shown in Fig. 8, Plate 58, having six flanges cast upon it, extending round the cylinder and supporting rings of firebrick, the bricks being secured by bolts passed down through holes drilled in each vertical row of the bricks. This construction was successful as regarded the firebrick casing, but it failed from a defect in the mode of making the joint to the wrought iron tube above, which was made by projecting jointed catches L on the top of the cast iron cylinder, resting upon lugs fixed inside the bottom edge of the wrought iron tube. These became overheated and gave way, in consequence of the furnace when standing during Sunday having been left charged full to the top, so that the cast iron cylinder was exposed to great heat at the joint without the cooling effect of the gas being drawn off: the cast iron cylinder was cracked, and in a day or two afterwards the wrought iron catches L became so softened by the heat as to give way and let the cylinder drop into the furnace. A plain cast iron cylinder rivetted upon the bottom of the gas tube was consequently substituted, as shown in Fig. 7, Plate 58, similar to the one used at Brymbo ; this has now been in use about four months, and the rivetted joint has proved quite satisfactory. It is contemplated to apply the gas from another furnace to heat the hot-blast stoves, in which case it is proposed to use a cylinder cased with firebrick, as shown in Fig. 8, but fixed simply by a rivetted joint at the top, as shown in Fig. 7 ; and there seems good reason to expect that the cylinder will then prove very durable, and last as long as the furnace hearth.

The main injury was found to be received by the cylinder when the furnace was standing. If it stood rather longer than usual at tapping time, the heat of the materials round the tube increased to such an extent on one or two occasions as to make the tube almost white hot. To prevent the present tube being injured in this way,

whenever the furnace has to stand any length of time for tuyering or any other purpose, the materials in the furnace are allowed to work down. As they work down towards the bottom of the cylinder, the quantity of gas passing to the boilers diminishes, so that the engine-man shuts it off from one boiler after another, until by the time the bottom of the cylinder is about to become uncovered it is shut off from the last boiler. If this should be omitted to be done soon enough, no explosion is found to result, but a back current from the boilers to the furnace is apt to set in and fire the soot and tar in the tubes; but these soon become extinguished when the valves are all shut. As soon as the blast is put on the furnace again, it is filled with one or two charges of materials which are kept at the furnace top ready; the valves at the boilers are then again opened, and a plentiful supply of gas is the immediate result. It was feared that in taking off the gas there might be a difficulty in the furnace standing for 12 hours every Sunday, as is the practice at the Old Park Iron Works; but by leaving it on the Sunday morning with the level of the materials below the bottom of the gas tube, no difficulty whatever has been experienced in letting the furnace stand as usual. Since the gas has been used, the last six barrows of coal and coke have been omitted in the last two charges every Sunday morning, for the purpose of lessening the amount of heat directly under the gas tube, without any injurious effect on the furnace.

The same plan of taking off the gas has also been employed for the last three months by Messrs. Fletcher Solly and Urwick at the Willenhall Furnaces, Willenhall, as shown in Fig. 4, Plate 57. In this case the gas is taken from one furnace out of three, and is burnt under the boilers of the blast engine, serving to raise all the steam for blowing the three furnaces. This application has proved so satisfactory that the apparatus is now being applied to one of the other furnaces, for the purpose of heating the hot-air stoves by the gas. In the boiler furnaces a little coal was at first kept burning, as a precaution to ensure the gas being always ignited; but it has not been considered necessary to continue this, and the firegrates have been covered with a layer of firebricks, as shown at M, Fig. 4, to

form a complete hot chamber for the combustion of the gas: this arrangement has now been in constant use for nearly two months without any objection being experienced. The chimney for the blast engine boilers is 120 feet high, and 8 feet diameter inside all the way up.

The cast iron gas cylinder G, Fig. 4, Plate 57, is in this case made bell-mouthed, as shown enlarged in Fig. 5; it is attached to the wrought iron tube A by four large wrought iron hooks L rivetted on the tube and catching lugs cast on the top edge of the cylinder; there are also four intermediate screw bolts and lugs N to hold up the cylinder in case of any of the hooks giving way. This cylinder was originally cased with firebricks, as shown in Fig. 5, but some of the firebricks have come off, in consequence of their being separately held by bolts screwed in the cast iron.

The furnace at the Old Park Iron Works was previously 8 feet diameter at the filling holes; but as it was desired not to diminish the area of opening at the top by the insertion of the gas tube, the furnace top was taken down about 9 feet, and rebuilt vertically, as shown in Fig. 2, Plate 56, so as to obtain a diameter of 10 feet at the filling holes. By this means the area of opening around the gas tube was made greater than the previous area of the entire open top. The portion of the gas tube A which descends into the material of the furnace is $4\frac{1}{2}$ feet diameter, giving 16 square feet area, and the annular area around it is $78 - 16 = 62$ square feet area; while the previous diameter of 8 feet gave only 50 square feet area. The effect of this increased area of opening at the furnace top is to allow the most complete freedom for the gas to escape at all times; for even if the gas valves be closed at all the boilers and no gas be used under them from any cause, there is still an area left one fifth greater than before for the gas to escape at the tunnel head.

The descending gas main B to the boilers, Fig. 2, Plate 56, is 16 square feet area. The chimney F is 130 feet high and $6\frac{1}{2}$ feet diameter inside at the top or 33 square feet area, and is sufficiently powerful to draw off ordinarily the whole of the gas from the furnace; as shown by the fact that the top of the furnace is frequently so free from flame that a person might safely walk across the top of the

materials. At times however, owing to the materials giving out more gas than is drawn down the tube and consumed under the boilers, a considerable quantity escapes in flame at the furnace top. This is an evident advantage of the plan of taking off the gas from an open-topped furnace; since the furnace is in no case liable to be injuriously affected by any back pressure, the open top around the gas tube acting always as a self-acting safety valve, which never allows the pressure inside the gas tube to exceed a definite small amount corresponding to the resistance of the 5 feet depth of materials through which any gas must pass that does not enter the tube. From experiments formerly made by Bunsen and Playfair it was found that the pressure that exists at 5 feet below the top of the materials in blast furnaces is equivalent to a column of water $\frac{1}{8}$ inch high. This is corroborated by the result of measuring the pressure in the top of the gas tube at the Old Park Iron Works, in which the above pressure was indicated at a time when there was a considerable quantity of gas escaping round the tube; at another time when scarcely any gas was escaping the pressure was found to be less than half that amount, being barely perceptible. It is a rather remarkable circumstance that every stroke of the blast engine was perceptible at the top of the furnace in the increased pressure of gas in the tube, as shown by an ignited jet of the gas issuing through a small hole in the tube, which increased and diminished with each stroke of the engine. From this it is evident that any restraint upon the free escape of the gas must have its effect upon the whole furnace, checking to a proportionate extent the entrance of the blast into the furnace, and consequently retarding its action and diminishing its make so long as such a back pressure exists.

The working of the open-topped furnace at the Old Park Iron Works from which the gas has been taken off has clearly proved that allowing the gas to escape at the furnace top with the greatest freedom possible is very beneficial to the working of the furnace; for since taking off the gas the average make per week has been greater than previously, while the materials used have been exactly the same. This will be seen by the following particulars, which are in the first place the amount of iron made by the furnace called No. 2 during the three months before the gas was taken off from it,

and also the make of another furnace called No. 3, of the same size, working at the same time, the same materials and same quantity of blast being supplied to each furnace: and secondly the make of the same two furnaces during the last three months, while the gas has been taken off from No. 2 and not from No. 3.

	No. 2 Furnace. Tons.	No. 3 Furnace. Tons.
Total make of iron during 3 months before taking off gas	1486	1519
Total make of iron during last 3 months with gas taken off from No. 2 furnace	1652	1545

This increased make may be partly accounted for by the increased amount of blast supplied to the furnace by the blast engine since the gas has been taken off, owing to the pressure of the steam being kept up more uniformly since the boilers have been heated by gas. It is also probably due in part to the combustion of the fuel at the top of the furnace being less rapid, in consequence of there being less heat at that part, which causes it to give out more heat and produce a better effect when it descends into the lower part of the furnace. This also accounts for a perceptibly greyer quality of iron being made by every furnace from which the gas has been taken off, when the same burden has been continued that was on the furnace before taking off the gas: except at Brymbo, where a leaner ironstone has been used since the gas apparatus has been at work. The increased make may also be partly due to the mode of filling, with the gas tube in the centre of the furnace top, which causes the materials to be spread in more uniform layers round the outside of the furnace. It is possible it may also to some slight extent result from a large proportion of the dust, which is thrown into the furnace along with the calcined ironstone and coke, being driven out of the furnace again through the gas tube, thus enabling the furnace to drive faster, in consequence of the blast not being impeded in its passage through the furnace by the presence of this useless dust.

At the Brymbo Iron Works the furnace No. 2 from which the gas is taken off has been working alongside another furnace No. 1 of rather larger size, both being fed with the same materials. The

following comparative statement shows the average weekly make of iron from each furnace for a whole year before the gas was taken off from No. 2 furnace, and for a corresponding period since:—

	No. 2 Furnace. Tons.	No. 1 Furnace. Tons.
Average weekly make of iron during 1 year before taking off gas	$104\frac{1}{4}$	$105\frac{3}{4}$
Average weekly make of iron during 1 year with gas taken off from No. 2 furnace	$108\frac{1}{2}$	$110\frac{3}{4}$

The result shows a slight increase in the average make of both furnaces since the gas was taken off, of about the same amount in each, namely 4 per cent. in No. 2 and $4\frac{3}{4}$ per cent. in No. 1 furnace.

The saving effected at Brymbo in cost of fuel for the blast engine boilers by taking off the gas is shown by the following statement of the consumption of slack, reckoned as good coal, during the two years before and after the gas apparatus was applied:—

Coal consumed at boilers per ton of iron made	before taking off gas	5·94 cwts.
Ditto ditto	after taking off gas	1·29 cwts.
	Saving	4·65 cwts.

Say $4\frac{1}{2}$ cwts. saving per ton of iron made, which at 3*d.* per cwt. makes 1*s.* $1\frac{1}{2}$*d.* saving per ton of iron made; and this on the total make of 11,285 tons of iron from the two furnaces during the year after taking off the gas amounts to a total saving of £635. This is exclusive of the saving of labour in firing, wheeling away ashes, and boiler repairs, the amount of which is considerably lessened.

The consumption of coal in the two furnaces at Brymbo per ton of iron made, during the same two years before and after using the gas from No. 2 furnace, was as follows:—

Coal consumed in furnaces per ton of iron made	before taking off gas	44·18 cwts.
Ditto ditto	after taking off gas	43·92 cwts.

The total consumption of coal per ton of iron made, including the blast engine boilers and hot-air stoves, was as follows:—

Total Coal consumed per ton of iron made	before taking off gas	52·09 cwts.
Ditto ditto	after taking off gas	47·01 cwts.

From this it appears that the total quantity of fuel consumed per ton of iron made has been less since the gas was used, although the furnaces have been supplied with a greater amount of lean ironstone during the latter period, as will be seen from the increased proportion of ironstone used per ton of iron made, which was as follows :—

Ironstone used per ton of iron made,		before taking off gas	61·95 cwts.
Ditto	ditto	after taking off gas	68·44 cwts.

being an increase of 10 per cent. after taking off the gas. Owing also to the greater leanness of the ore, a greater proportion of lime had to be used in the furnaces, the amounts of calcined limestone per ton of iron made being as follows :—

Calcined Limestone per ton of iron made		before taking off gas . . .	15·08 cwts.
Ditto	ditto	after taking off gas	16·86 cwts.

being an increase of 12 per cent. in the latter period.

As regards the quality of the iron produced there was no perceptible difference before and after taking off the gas : and from the foregoing particulars it is evident that, if the ironstone had been of equal quality after taking off the gas, the iron produced would have been of a greyer quality ; since rather less coal in the furnace has sufficed to reduce 10 per cent. more ironstone and 12 per cent. more lime. This is confirmed by the experience of the working at the Old Park Iron Works, the Willenhall Furnaces, and the Barrow Furnaces near Ulverstone, where the same burden of coal has produced iron of a slightly greyer quality since the gas has been taken off.

The working of these furnaces appears to lead to the conclusion that the open-topped plan of taking off the gas is preferable to the use of a close top; for with the latter there is occasionally a considerable pressure on the materials at the top of the furnace, owing to its producing at times more gas than is drawn off. This has a tendency to change the quality of the iron produced from grey to white, as was proved at the furnace at Bilston previously referred to; and accounts for close-topped furnaces in general working with greater irregularity than open-topped ones. No doubt this

disadvantage in close-topped furnaces might be in a great measure obviated by the use of a sufficiently powerful chimney to draw off the maximum amount of gas produced by the furnace; but even then the close-topped plan has the disadvantage that the level of the materials in the furnace cannot be seen, which often causes it to be irregularly filled; whereas in the open-topped furnace the fillers have their eye continually on the level of the materials, and have no excuse for the furnace not being always kept full. With a chimney of sufficient height it has been seen that the whole of the gas is drawn off from the open-topped furnaces, except at the times when an excess of gas is made in the furnace, which should be allowed to escape under all circumstances, to prevent the working of the furnace being interfered with; but with close-topped furnaces it has to be observed that the loss of gas, which inevitably occurs at each time of opening the top for filling, takes place at all times, whether there is a surplus supply of gas or not.

This open-topped plan can be readily adapted to any existing furnaces without the necessity of raising their height, as is requisite with the close-topped plan to allow room for the apparatus. It is also worthy of note that the working of every furnace where this plan has been tried has been improved, which the writer believes is not the case where a close top is used. In several furnaces working with close tops a larger quantity of fuel has been found necessary to produce the same quality of pig iron. In one case at Middlesborough, where a superior description of close top is used, the furnace takes 5 to 7 per cent. more fuel per ton of iron made. At another ironworks there the writer was informed that the extra quantity of fuel required by the furnaces when working with close tops quite counterbalanced the saving of slack at the boilers. This is directly contrary to the experience of those who have used the open-topped plan described in the present paper. There is one point of difference between the two plans which must not be left unnoticed: with a close top the gas may be burnt under boilers, in stoves or heating furnaces, without any high chimneys being necessary to create a draught, the gas being forced down from the furnace by not being permitted to escape at the tunnel head; whereas with an open top a chimney of sufficient height and area to

produce a good draught is essential to draw off the whole of the gas produced by a furnace. The writer believes however that a close-topped furnace would work much better if the whole of the gas were drawn off as it rises, and that there is a loss instead of any saving in not providing sufficiently powerful chimneys to effect this; the experiment made at Bilston having clearly proved that any pressure of gas in the furnace top is injurious, at least with Staffordshire materials.

In conclusion the writer would remark that the object of this paper is to elicit the facts as to the respective advantages of the several plans that have been tried for using the waste gas from blast furnaces, so as to aid if possible in overcoming the difficulties that have been met with hitherto in its utilisation, and to lead to the general adoption of this important source of economy, which is more especially desirable in the South Staffordshire district since the principal seams of coal are becoming so rapidly exhausted. Only six months ago no use was made of the waste gas from any one of the 126 furnaces then in blast in this district; and at the present time it is only made use of from three, namely one at Wednesbury, one at Willenhall, and one of Mr. Blackwell's at Dudley. In Scotland the plans tried some years ago failed to produce any economical result, so that they were abandoned; and no use is there made of the waste gas up to the present time. In the other iron-making districts of England it is economised at some works but not at others, though the advisability of doing so is now almost universally admitted; and the writer feels sure that in a few years there will not be many ironworks where it is not made use of. The great importance of the question is apparent on considering that the saving effected by making use of the waste gas from one furnace on the plan now described is equal to from £500 to £1000 a year, according to the value of slack at different works. Taking the average saving at £750, if the plan were adopted at only 100 of the 126 furnaces now in blast in South Staffordshire, an annual saving of no less than £75,000 would result to this district alone.

The CHAIRMAN observed that the plan described in the paper just read appeared a very simple arrangement for taking off the waste gas without the necessity for a close top to the blast furnace. They had had a description of a close-topped furnace at the previous meeting, and he thought it would be desirable to know the further results of its working since that time for comparison with the present open-topped plan.

Mr. C. COCHRANE said the statements given at the previous meeting respecting the working of the close-topped furnace at Middlesborough then described had been fully confirmed by subsequent results. The close-topped furnace from which the gas was taken off was one of three furnaces, all working under the same conditions of materials and blast; and the results of working for the month of September were that the average quality or "number" of iron made by the close-topped furnace during the month was 3·16, taking the range of numbers 1 to 4 for foundry iron and 4 to 6 for forge iron, and the two other furnaces yielded average qualities of 3·18 and 3·01, showing no appreciable difference in quality in the make of the close-topped furnace. The consumption of coke was 31·89 cwts. per ton of iron in the close-topped furnace, and 31·21 cwts. and 31·02 cwts. in the two other furnaces, showing a consumption of 2 per cent. and 3 per cent. more coke respectively in the close-topped furnace, which was a further improvement as had been then anticipated upon the result stated at the previous meeting, when the consumption of coke had been reduced from 7 per cent. to 5 per cent. greater in the close-topped furnace. The total make of iron in the close-topped furnace during the month was 818½ tons, of which 31 tons were mottled iron and 16½ tons white iron, amounting altogether to less than 6 per cent. of mottled and white iron out of the whole quantity. In some close-topped furnaces the working of the furnace was impaired by the mode of filling, the top being closed by a cone that was lowered into the furnace in charging, which reduced the height of the materials, so that the heat was not so thoroughly taken up and a greater consumption of coke was required; but by having the cone made to draw upwards for charging, on the plan he had adopted, the materials could be kept up to the same height as before, and any objection on this ground removed.

One cause of the increased make of the furnace described in the paper had he thought been overlooked, namely the improvement arising from enlarging the tunnel head; for it was well known that a wider mouth increased the make of a furnace, by allowing a larger quantity of blast to pass through it than was possible with the smaller top.

Mr. G. Thomson asked whether the 31 cwts. of fuel consumed in the close-topped furnace per ton of iron made was coke or coal.

Mr. C. Cochrane replied that the fuel was all coke, as they could not use their coal in the blast furnace, since it would cake and arch over and check the working of the furnace.

Mr. J. Fenton thought the make of the open-topped furnace described in the paper, 104 tons per week, seemed a small amount for a hot-blast furnace; and he enquired what was the temperature of the blast, and whether the ore was calcined before going into the furnace. At Low Moor the weekly make of one large furnace was about 120 tons of cold-blast iron, from a lean stone containing only 28 per cent. of iron; the furnaces were rather larger than that described in the paper, measuring about 12 feet diameter at the top and 14 feet at the boshes. He asked whether the limestone used was carboniferous or magnesian.

Mr. Lloyd said the temperature of blast was about the melting point of lead, but sometimes below. The ironstone used at Brymbo was of a lean description, containing only about 26 per cent. of iron, so that the make of the furnace was rather less than would be got with such an ore as had been mentioned. In the furnace at Wednesbury, the make of which was about 124 tons per week, the ironstone used was chiefly that known as Blue Flat, containing rather more than 30 per cent. of iron; and also New Mine ironstone, containing about 25 per cent. of iron: the quality of iron produced was very good. The ore was calcined beforehand, and the limestone was the silurian. The furnace was 10 feet diameter at the top, 12 feet at the boshes, and 4 feet 6 inches in the hearth, and the total height was 47 feet to the level of the filling plates.

Mr. W. Mathews observed that if the coal was not precisely the same in quality in both cases, the make of iron would of course be different: he had had an opportunity recently of seeing the working of the furnaces at Low Moor, and was satisfied the difference in quality

of coal fully accounted for the difference in make; and if the coals used at the two works were interchanged, the make of the furnaces would be reversed. The coal used at the Old Park Iron Works was not a good coal for the blast furnace as compared with that used at Low Moor, and the make of iron obtained he considered was good work for such a quality of coal; but the superior coal at Low Moor made both a good quality of iron and a good yield.

Mr. J. Fenton asked whether the coal was all coked or used raw.

Mr. Lloyd said that half of each burden consisted of Heathen coal and Thick coal mixed, and was used raw; but the other half consisting of New Mine coal was coked before being used, to get rid of the sulphur which it contained in its raw state.

Mr. E. A. Cowper thought there was no doubt the increased make of iron obtained after taking off the gas was due to the increased quantity of blast delivered into the furnace, owing to the increased supply of steam to the blast engine when the boilers were heated by the gas, all risk of neglect or irregularity in the firing being removed; this seemed the most satisfactory explanation, because the make was increased in both furnaces, not that only from which the gas was taken off. The utilisation of the waste gas was of the utmost importance to the welfare of the South Staffordshire district, as it would result in the manufacture of iron being cheapened; he was glad that attention was now being called generally to the subject.

Mr. N. N. Solly had had the gas taken off for three months from one furnace at Willenhall in the manner described in the paper, and the one furnace supplied gas enough for all the four boilers of the blast engine, without the use of any slack at all, except during the first week of starting, when a little slack had been burnt for ensuring keeping up the steam while the furnace from which the gas was taken off was standing. There were three furnaces of 11 feet diameter at the top and 14 feet 6 inches at the boshes, each making about 170 tons of iron per week, and the iron made by the furnace from which the gas was taken off was rather greyer than in the two other furnaces with the same burden of coal, which showed an advantage in taking off the gas; there had never been any white or mottled iron from that furnace since the gas was taken off, and the furnace had never

slipped in the least, but worked with great regularity. The quantity of iron made per week was not altered since the gas was taken off, but the yield of the ironstone was decidedly better than in the other two furnaces; and the yield of coal was also better, though this might be partly accounted for by the furnace having had a new hearth recently: the coal used was entirely New Mine coal, which was a pure coal, but not strong for standing the blast.

Mr. W. Mathews asked whether the distance of the boilers from the blast furnace made any difference in the efficiency of the gas; he supposed there would be no difference, because the gas was not ignited till it reached the boilers, and was therefore conveyed to them simply like common coal gas. He had long felt the importance of utilising the waste gas, but had hesitated to apply it at his own furnaces, principally for the reason that it would have to travel a long way to reach the boilers, past the blast engine and over a road: he had therefore delayed taking off the gas, as many other ironmasters doubtless had done, till he had seen the results of the trials at other places. No previous mode of taking off the waste gas had appeared quite free from objection, but the plan now described seemed to answer completely, and Mr. Blackwell had also tried the same plan recently with most beneficial effects. He fully expected now that the bulk of the furnaces in South Staffordshire would have the gas apparatus applied before long. The relative cost of slack in different districts was of course a question that would affect the value of the plan materially, and in the North of England where its cost was rather excessive it was more necessary to save fuel by taking off the gas; but at his own works only 4 or 5 cwts. of slack were burnt under the boilers per ton of iron made, and as the slack was delivered very cheap from the pits close by there was but little margin for economy. At many works in the district however fuel was much dearer; and in the present state of the iron trade the smallest saving was of importance, particularly when the ultimate exhaustion of the present local supply of coal was taken into consideration.

An important application of the small coal of the district was now being carried out by Mr. Charles Cochrane, who had recently put up some ovens at Dudley for converting it into a serviceable coke by

mixing with it some bituminous slack from South Wales; by this means he had succeeded in making a good useful coke out of what was otherwise of no use but to burn under engine boilers. The cost of Welsh small coal limited the adoption of such a plan at present, but this would soon be materially reduced by increased facilities for carriage by railways, which would almost make South Wales and South Staffordshire parts of the same district, as North and South Staffordshire were now become one district by the extension of railway communication.

Mr. Lloyd said there was no difficulty or objection to conveying the gas a considerable distance from the furnace, and there was not the slightest difference in its efficiency, whatever distance it was conveyed to; just as the gas supplied to Birmingham from Westbromwich was exactly the same in Birmingham as at the works 6 miles off.

Mr. E. A. Cowper stated that the gas was conveyed 400 or 500 feet at Messrs. Bolckow and Vaughan's furnaces at Eston near Middlesborough, without any difficulty; it was only necessary to have sufficient draught or pressure to overcome the friction of the gas along the pipe. These furnaces had the top closed for taking off the gas with a cone or bell that was lowered for charging, and were making grey foundry pig. He asked whether the waste gas had been applied to the hot-blast stoves in any of the cases described in the paper, as well as to the boilers.

Mr. N. N. Solly said the gas was not yet employed for heating the hot-blast stoves at the Willenhall Furnaces, but they were getting ready for applying it for that purpose; the gas would be taken in at the top of the stoves, and out at the bottom, and thence along a culvert to the chimney, which was 120 feet high and 8 feet diameter inside all the way up.

Mr. Lloyd observed that in this plan of taking off the waste gas by a tube inserted in the materials of the furnace there was found to be a great accumulation of dust in the bend at the top of the furnace, the bend being sometimes half full of dust after a week's work, and a valve had to be placed there for raking out the dust every Sunday. This dust consisted of little shelly pieces of ironstone mixed with

coke dust, which was of no use in the furnace, and must cause an obstruction to the blast by going down with the materials; and he thought the circumstance of its being drawn off with the gas in this plan accounted partly for the increased make of the furnace since the gas was taken off, by relieving the furnace and allowing the blast to pass through more freely. They had tried carefully puddling two or three heats from this furnace and from the two other ordinary furnaces, and the result seemed a little in favour of the furnace from which the gas was taken off, 2 lbs. more weight of wrought iron being obtained in one case and 3 lbs. in another out of a charge of 4 cwts. of pig iron.

Mr. F. J. Bramwell remarked that in former trials of close-topped furnaces the inferior quality of iron obtained was considered to arise not from the pressure of gas produced by the closed top, but because the waste gas burning out of the tunnel head in ordinary open-topped furnaces produced a beneficial effect in preparing the charge for going down into the furnace, which was lost when the top of the furnace was closed; but if only the surplus gas was drawn off by the centre tube in the plan now described, leaving enough still burning out of the open furnace top, this effect would not be interfered with. He enquired whether the gas was ever so completely drawn off that no flame at all was visible at the tunnel head, and if so whether any difference had been observed in the iron produced during that time.

Mr. Lloyd replied that sometimes all the flame went down for a short time, with scarcely more than that of a candle to be seen playing at intervals through the crevices of the materials, so that a man could even walk across the top of the furnace; but this absence of flame never continued more than a quarter or half an hour, so that there was no means of judging whether the make of iron was affected by it. He thought the materials in the furnace must give out very variable quantities of gas, as there was so much variation in the flame burning out at the top.

Mr. N. N. Solly said he had never seen his furnace entirely free from flame, but there was much less flame at some times than at others, and frequently scarcely any.

Mr. C. Cochrane thought nearly all the gas must be taken off by the centre tube, if the flame at the tunnel head was so small as frequently to be scarcely visible; and the small quantity of gas burning out at the open top could produce but little beneficial effect on the materials. In such cases the open-topped plan of taking off the gas seemed to be practically under the same condition as a close top with the whole of the gas taken off.

Mr. Lloyd observed that the open top was a safeguard against any risk of the furnace being thrown to white iron when there was much gas given off from the materials. On one occasion he had observed a large quantity of flame at the tunnel head, and if the top of the furnace had been closed white iron would he thought certainly have been made then. If a comparison were made in the South Staffordshire district between the two modes of taking off the gas, with a close-topped and an open-topped furnace working side by side, he had no doubt the open-topped furnace would prove decidedly the better; for in the previous trials they had made of close-topped plans, the iron was soon found to be injured in quality and the make fell off from 100 tons per week to 60 tons.

The Chairman enquired whether any accidents from explosion had occurred at any of the furnaces from which the gas was taken off.

Mr. N. N. Solly had had no accident that had caused any damage, and no explosion of gas in the gas main had ever occurred at his furnaces, but the gas main was fitted with a considerable number of safety valves. There had been two slight explosions in the fore portion of the blast pipes, but they were not sufficient to do any injury to the apparatus or machinery; they arose from want of safety valves on that part of the pipes, but two had now been added there, and since then no accident had occurred. Explosions generally occurred at casting time, when the gas was prevented from escaping through the gas main by a damper which was then shut to stop the draught; and the gas being kept back and confined in the furnace must have found its way through the tuyeres into the blast pipes, and there mixing with air exploded in the fore portion of the pipes in front of the furnaces. No such explosion ever occurred before the gas apparatus was put up, because then the gas could always escape

sufficiently at the tunnel head at casting time; and they had previously taken the precaution to place valves on the blast pipes at the back of the furnaces.

One effect of this mode of taking off the waste gas was he thought that the draught of the chimney removed much of the sulphur and other impurities from the furnace, enabling a superior quality of iron to be made. Besides the saving of fuel produced by using the gas, there was as much advantage to be gained from the saving of labour in boiler repairs; for since the gas had been used he had not had the slightest repairs to the boilers, whereas previously repairs were required almost every week: the attendance of stokers for the boilers was also saved, and labour and horse power for removing ashes, &c.

Mr. C. Cochrane said there was little danger of explosion in taking off the gas, if there was a proper arrangement of tubes and sufficient provision of safety valves. He had now had the close-topped furnace at Middlesborough at work for eleven months since first starting, without a single explosion to do any mischief.

Mr. C. W. Siemens thought there was less risk of explosion in taking off the gas from a close-topped furnace, because there was no chance of any admixture of air taking place; but in an open-topped furnace the draught of the chimney might draw in air through the end of the tube when the furnace stopped, and make an explosive mixture.

Mr. C. Markham said at the close-topped furnaces at Marquise in France, that he had mentioned at the previous meeting, there were no safety valves, and there had never been an instance of the gas exploding; but he doubted whether safety valves would be of much use in case of explosion, as the explosion would be instantaneous, and he thought the mischief would be done before the safety valves had time to act.

Mr. C. Cochrane considered the safety valves were essential as a precaution against damage by explosion; for they had frequently had explosions at Middlesborough in which the safety valves were the only safeguard, and the entire apparatus would have been blown to pieces had there been no valves; but the valves flew open at the instant of explosion, and completely prevented all injury.

Mr. LLOYD said their gas main had been saved by the safety valves several times from being blown up by explosions when they tried using the gas about ten years ago; the valves shot open suddenly, and the men standing near had been blown down, but no damage was done. No explosions had occurred since they commenced taking off the gas on the present open-topped plan.

The CHAIRMAN asked whether there was a damper for cutting off the draught of the chimney at casting time.

Mr. LLOYD said there was a slide valve in the gas main at each boiler, which was shut when the furnace was standing, but the furnace continued making a little gas at that time, which came down into the main mixed with air and sometimes exploded when lighted again. He proposed providing a stop valve at the top of the descending gas main close to the bend, to be closed when the furnace was standing; the seating might be made with a deep groove all round, which would become filled with the dust drawn over from the furnace, and the rim of the valve bedding in the dust would form a gas-tight joint; this would be an improvement by entirely preventing either gas or air from passing into the main while the furnace was standing.

Mr. E. A. COWPER remarked that where there were several furnaces connected to the same gas main there might be danger of drawing in air through one furnace that was standing, while gas was being drawn off from the others, forming an explosive mixture in the gas main. At some furnaces in the North of England the gas was taken off from all the furnaces by one large main, 6 feet diameter, with a row of safety valves all along the top; when an explosion occurred there, it ran along the main, all the valves lifting successively, and no injury was done.

Mr. LLOYD observed there was one difficulty they had experienced in taking off the gas, which had not arisen in other cases: a considerable quantity of pitch was deposited in the gas main, which caused great annoyance, blocking up the bends and choking the slide valves leading to the boilers; they were obliged to get a red-hot iron to melt the pitch in order to open the valves, and men had to be sent down the descending gas main to clear it out. This trouble had

not occurred in South Wales or at Brymbo; and at Willenhall, where it was experienced slightly at first, it was now no longer met with.

The Chairman observed that the subject of the paper was one of great importance, and he hoped it would be carried on at a future meeting with the results of continued experience in this mode of taking off the waste gas. He proposed a vote of thanks to Mr. Lloyd for his paper, which was passed.

The following paper was then read :—

DESCRIPTION OF A NEW SAFETY COUPLING FOR RAILWAY WAGONS.

By Mr. CHARLES MARKHAM, of Derby.

It is remarkable that, notwithstanding the numerous improvements which have been made in all kinds of machinery during the last twenty years, some simpler mechanical contrivance has not been introduced to supersede the present rude and dangerous method of coupling railway wagons. Numerous attempts have been made at different times to accomplish this desirable object, but they have been abandoned in consequence of being found defective in working.

In the early period of railways, when the different lines were isolated from one another, the centres and heights of the wagon buffers were considered to be of little importance, and each railway adopted some dimensions of its own. When however it became evident that for the accommodation of the traffic wagon stock of the same gauge must circulate from one end of the country to the other, uniformity in the centres and heights of the buffers became necessary. Resolutions were consequently agreed upon at the clearing house that the height from the rails to the centre of the buffers should be 3 feet 3 inches, and the distance from centre to centre of the buffers 5 feet $8\frac{1}{2}$ inches; the length of the buffers was fixed at 1 foot 3 inches for dead or solid buffers and 1 foot 6 inches for spring buffers. These regulations have been in force for many years, and a considerable degree of uniformity now prevails in the general construction of railway plant, which materially tends to facilitate the introduction of a coupling that can be connected to any modern description of wagon.

No class of railway servants are subjected to so dangerous an occupation as "shunters," who are employed in marshalling and forming goods and mineral trains, and are continually coupling and uncoupling wagons, frequently whilst in motion; this they generally

accomplish by leaning on the buffers, and lifting the coupling link on or off the drawhook. If the buffers are compressed together when the engine starts and pulls the wagons forward, or if the engine-driver misunderstands the signals and suddenly checks the engine when pushing, the shunter is liable to fall in between the buffers on to the rails and be crushed or mutilated by the wagons passing over him; and fatal accidents from this cause are very numerous.

The writer has now the pleasure of bringing before the meeting a new Safety Coupling for Railway Wagons, the invention of which is due to Thomas Osborne, who has been employed for many years as a fitter on the Midland Railway. A model of the coupling was shown to the writer by him about two years ago, but the invention at that period was in a crude and imperfect form; and as the coupling operation had still to be performed by the men going in between the buffers, the plan was considered to be of no practical value. With the assistance however of Mr. Harland, chief foreman of the Midland Railway carriage shops at Derby, the present plan of this coupling has been matured so that it can be successfully employed.

The new coupling is shown in Plates 59 and 60. Fig. 1, Plate 59, is a longitudinal section, showing the coupling at one wagon end in the position when coupled, and that at the other wagon end hanging loose when uncoupled; and Fig. 2 is an end elevation with the coupling in the latter position. Figs. 3 and 4, Plate 60, show the process of coupling and uncoupling: Fig. 5 is a side elevation, and Fig. 6 a plan of the coupling. The coupling consists of a straight double link AA, Figs. 5 and 6, connected at one end by a pin to each side of the shank of the drawhook, whilst the outer ends are connected to the coupling link B by means of the pin C. This pin has a projection or tripping catch D forged upon it in the middle, and its ends are flattened and fit into corresponding holes in the coupling link B, as shown in Fig 5, so as not to turn in it. The coupling link has its straight ends prolonged backwards beyond the pin for carrying the counterbalance weights E, which serve to keep it in its proper position for being acted upon by the lifting lever when the operation of coupling is to be performed. The lifting lever F is worked from either side of

the wagon by the handles G G on the ends of the transverse shaft H, Fig. 2, which is carried in hangers from the sole bar of the wagon. Each wagon has a similar coupling at each end if desired; and when two wagons are coupled together, the link which is out of use remains suspended in a vertical position, as shown in Fig. 1.

In coupling the wagons together by this apparatus, the lifting lever F is raised by the handle G, and bears against the nose of the tripping catch D, as shown dotted in Fig. 3, Plate 60; thereby raising the link B, until it obtains a bearing on the underside of the catch, when it throws out the coupling link B, which is thus brought over the opposite drawhook, as shown full in Fig. 3, and is then allowed to drop on the hook by lowering the lever. In order to uncouple the wagons, the link is first raised by the lever till it is disengaged from the drawhook, as shown dotted in Fig. 4; and is continued to be raised still further until the nose of the tripping catch escapes the end of the lever, when the coupling link is tipped up by the counterbalance weights E into a vertical position, as shown full in Fig. 4; and is then lowered by the lever, clear of the drawhook, into its original suspended position. A stop I, Figs. 1 and 2, is provided inside the coupling link B, which comes against the side link A to prevent the coupling link tipping over too far back.

The mechanical success of the plan now described for coupling railway wagons is due to the introduction of the elbow joint and tripping catch in the middle of the coupling, whereby the coupling link is enabled to pass up clear of the opposite drawhook in lifting, and is then extended forwards to reach over the hook for coupling the wagons; while in uncoupling, it is first disengaged from the hook and lifted up, and then swings free into a vertical position, so as to drop clear of the hook in lowering. The advantages attained in this plan are safety to the men, dispatch in the process of coupling and uncoupling, and certainty of action. The coupling consists of few working parts, and these are not liable to derangement in the ordinary working of railway wagons; but even in the event of the lifting lever accidentally getting out of order, the coupling can be made use of as an ordinary coupling by being lifted on or off the drawhook by hand. The coupling can be applied to any wagon with the same facility as an ordinary coupling,

with the exception of the extra cost of labour and material for the levers for working it; it can also be easily coupled to another wagon, even though there should be a difference of 6 inches in the length of the buffers. The difficulty of coupling wagons together on a sharp curve, in consequence of their being out of line with one another, has been provided for by widening the opening of the coupling link B and lengthening the centre pin C, as shown in the plan, Fig. 6, Plate 60, so that the link has a sufficient opening to ensure its always engaging the opposite drawhook, even on a sharp curve; while the side links A A of the coupling are kept straight, to withstand the violent jerks which all wagon couplings are subjected to.

For testing the efficiency of this coupling a wagon fitted with it was attached to the shunting engines that are employed in sorting and marshalling trains at the Derby station, and was kept constantly at the work both night and day for about two months; the very heavy trains that had to be shunted and the great variety of wagon stock that passed through the station in transit to different parts of the country afforded an excellent opportunity of detecting any defects that might exist in its application. The result of this trial showed that nearly the whole of the wagon stock on the Midland Railway, including upwards of 17,000 wagons belonging to colliery proprietors and others connected with the coal trade, could be coupled or uncoupled with the greatest facility by means of the new coupling. The variation in length of the buffers of the different wagons now in ordinary use and running in connexion with the Midland Railway does not exceed 6 inches, as seen by the Table appended; and there does not therefore appear to be the slightest objection to the universal application of this mode of coupling to all such wagons. Some wagons however of an old make, belonging to the London & North Western and Manchester Sheffield & Lincolnshire Railways, have no drawhooks; consequently in such cases the men must couple the wagons in the ordinary method; but these cases are the exception to the general rule, and in a few years will be entirely removed by the substitution of an improved description of wagon stock constructed in conformity with the general regulations of the clearing house.

Projection of Buffers beyond Drawhooks.

	Projection. Inches.	Variation. Inches.
Midland Railway	8, 5, 2	6
Manchester Sheffield and Lincolnshire .	8, $3\frac{1}{2}$, 3, 2	6
London and North Western . . .	$5\frac{1}{2}$, 5, 4, $2\frac{1}{2}$, 2	$3\frac{1}{2}$
North Staffordshire	5, 3	2
North Eastern	$3\frac{1}{2}$, $2\frac{1}{2}$	1
West Hartlepool	3	0
South Staffordshire	5	0
West Midland	$4\frac{1}{2}$	0
Extreme dimensions	8 and 2 inches	6

The principal impediment to the immediate introduction of the new safety coupling will be its extra cost as compared with the ordinary coupling, the cost of each plan being as follows :—

Ordinary coupling.

	s.	d.
$35\frac{1}{2}$ lbs. of iron at $1\frac{1}{8}d.$ per lb.	3	4
Labour		8
Total	4	0

New coupling.

	s.	d.
46 lbs. of iron for coupling, at $1\frac{1}{8}d.$ per lb.	4	4
Labour	5	5
18 lbs. of cast iron for balance weights, at 7*s.* 9*d.* per cwt. .	1	2
Labour		5
51 lbs. of iron for lifting lever, shaft, hangers, &c., at $1\frac{1}{8}d.$ per lb. . .	4	9
Labour	4	7
Total	20	8

The extra cost of the new coupling is thus 16*s.* 8*d.* for each coupling, or £1 13*s.* 4*d.* for both ends of the wagon.

There does not appear to be any doubt respecting the successful application of the new coupling in its present form : but the writer thinks it may be advisable to increase still further the size of the rods, levers, and pins, since they may possibly be found too light as at

present made; for experience has shown the necessity of making every description of rolling stock strong enough to withstand the violent concussions it is liable to.

Mr. Markham showed a full size working specimen of the coupling in action, which could be altered to allow of 6 inches variation in the distance between the drawhooks, for exhibiting the range of action of the coupling. He observed that a previous attempt had been made at a mechanical coupling to supersede the present mode of coupling by hand, the coupling link being lifted by a lever from the side of the wagon; but the link was made in a single length without a joint, and would therefore work only with a uniform length of buffers, and if the buffers were at all short the link did not drop into the drawhook till the wagon was started. In the new coupling however the principal element of success was the elbow joint in the middle, which enabled the coupling link to reach over the drawhook even with the extreme variation that was met with in length of buffers, amounting to as much as 6 inches. With the present mode of coupling by hand the loss of life was fearfully great, and the accidents were extremely numerous, far more so than was generally known; it was therefore of the greatest importance to prevent the continuance of such accidents by the adoption of some such mechanical coupling as that now described.

The Chairman enquired to what extent the new coupling was now in use.

Mr. Markham said there were about eight sets of the couplings now in use on the Midland Railway, and one had recently been put to work on the Manchester Sheffield and Lincolnshire Railway.

Mr. J. Wright fully concurred in the importance of adopting some mechanical mode of coupling to prevent the loss of life and accidents occurring under the ordinary mode, which to his own knowledge were lamentably extensive. He had not yet seen the new coupling in operation, and hoped a thorough trial would be made of it on several railways, in order to test its working under a variety of circumstances.

The coupling appeared a good deal heavier and more costly than the ordinary couplings, and he thought it would be a great advantage if it could be somewhat simplified ; for a chief source of expense in wagon repairs was the loss of the couplings, which were generally broken off at the pin so that the whole coupling was lost, and if any of the new couplings were lost they would entail a great expense for renewal.

The CHAIRMAN observed that the first cost of the new coupling must be considered in connexion with its durability, and as a means of saving accidents and loss of life it deserved the best attention of all railways, and he hoped it would have a careful trial. He proposed a vote of thanks to Mr. Markham for his paper which was passed.

The following paper was then read :—

DESCRIPTION OF A STEAM HAMMER FOR LIGHT FORGINGS.

By Mr. RICHARD PEACOCK, of Manchester.

Power hammers are almost indispensable for the production of sound smith's forgings, and their extensive introduction into the smithery has been attended with most valuable results. Their application is not of recent date, but the extraordinary demand for forged iron work for steamboat and railway work has given an impetus to their use, and their adaptation to the more general wants of the smith's shop is marked by great advantage as regards both efficiency and expedition.

The Steam Hammer described in the present paper, and shown in Plates 61 to 63, is now in use at the author's works, Gorton Foundry, Manchester; and is brought before the meeting by request, as an example of a practical and useful steam hammer for light forgings, heavy smith's work, stamping, &c. This hammer is worked by hand, and is either single or double acting: that is it can either be lifted by steam and allowed to fall by gravity alone; or after it has been lifted, steam can be used above the piston to give increased effect to the blow. Fig. 1, Plate 61, is a vertical section of the hammer, and Fig. 2, Plate 62, a side elevation; Fig. 3, Plate 63, is a sectional plan through the steam cylinder and valve chest, to a larger scale.

The steam cylinder A, Fig. 1, Plate 61, is 10 inches diameter and constructed for a 24 inch stroke. The valve B is cylindrical, turned to fit well in the valve chest but to move easily within it. The top end of the valve is made longer on one side than on the other, as shown in Fig. 1 and enlarged in Figs. 4 and 8, Plate 63; and when the valve is in the position shown in the plan, Fig. 7, steam is admitted above the piston in the down stroke, as in Fig. 6;

but by turning the valve half round by the handle C, as shown in Fig. 3, the additional lap prevents the admission of steam above the piston, as in Fig. 10, and allows the hammer to fall by gravity alone. Figs. 4 to 6 show the top, middle, and bottom positions of the valve when turned for admitting steam above the piston in the down stroke; and Figs. 8 to 10 show the same positions when the valve is turned half round to exclude the steam from the top of the piston. The valve is worked up and down by the hand lever D, Fig. 2, Plate 62; it is open through the centre, and the weight of the valve, valve rod, and hand lever is counterbalanced by the spiral spring E. To prevent the piston from rising too high in the cylinder, a trigger F, Fig. 1, is fixed on the side frame, which when struck by the roller G on the hammer block H lowers the valve and allows the steam to escape from beneath the piston.

The piston is secured to the rod in the usual way by a cone and nut. The bottom end of the rod has a solid head I, Figs. 11 and 12, Plate 63, by which it is secured to the hammer block H; this head is rounded on the top and bottom and is made $\frac{1}{4}$ inch less in diameter than the hole in the hammer block, to allow of any twist or vibration, in order to prevent the breaking of the piston rod, which from the oblique strain due to the varied character of the forgings has hitherto given great trouble in steam hammers. The weight of the piston, piston rod, and hammer block is $12\frac{1}{2}$ cwts. or 1400 lbs.

Plates 64 to 66 give a number of indicator diagrams taken to show the approximate effect of the blows when working the hammer single and double acting, and with various lengths of stroke, with steam at 50 lbs. per square inch pressure in the boiler.

The diagrams in Fig. 13, Plate 64, are taken below the piston, the hammer working with a stroke of 20 inches at 83 blows per minute, and falling by gravity alone. From these diagrams it will be seen that the mean pressure of steam in lifting the hammer is 25·7 lbs. per square inch, which multiplied by 66 square inches area of the lower side of the piston is equal to 1696 lbs. total; and the mean back pressure against the hammer when falling, including cushioning, is 4·3 lbs. per square inch, or 284 lbs. total. Fig. 14 is

a diagram taken above the piston, showing that a partial vacuum is formed above it in falling, equal to 1·6 lbs. per square inch, or 126 lbs. total on 78·5 square inches area of the top of the piston: this added to the back pressure below the piston gives a total retarding pressure of 410 lbs. to be deducted from the weight of the hammer. Thus the effective weight of the hammer is 1400 lbs. less 410 lbs., or 990 lbs.; say 9 cwts., or 29 per cent. less than the real weight of the falling mass. This weight multiplied by the height of the fall, 20 inches, gives an effective blow of 1650 lbs. or $14\frac{3}{4}$ cwts. falling 1 foot: friction not being taken into account.

The diagrams in Fig. 15, Plate 64, are taken below the piston when steam is used above, the hammer working with the same stroke of 20 inches at 112 blows per minute: the mean pressure in lifting the hammer is equal to 30·1 lbs. per square inch, or 1987 lbs. total; and the mean back pressure when the hammer is falling is 5·4 lbs. per square inch, or 356 lbs. total. The diagrams in Fig. 16 are taken above the piston, when steam is used above, the hammer working as before with a stroke of 20 inches at 112 blows per minute: the mean pressure of steam during the down stroke is 32·1 lbs. per square inch, or 2520 lbs. total; and the mean back pressure above the piston when rising is 8·8 lbs. per square inch, or 691 lbs. total. Hence the effective pressure of the steam on the top of the piston is 2520 lbs. less a back pressure of 356 lbs., or 2164 lbs.; which added to the weight of the hammer gives a total effective weight of 3564 lbs., or $31\frac{3}{4}$ cwts. This weight multiplied by the height of the fall gives an effective blow of 5940 lbs. or 53 cwts. falling 1 foot, when the steam is admitted above the piston: which compared with the blow of $14\frac{3}{4}$ cwts. when the hammer falls by its weight alone shows an advantage of $3\frac{1}{2}$ to 1.

The diagrams in Fig. 17, Plate 65, are taken below the piston, the hammer working with a stroke of 10 inches at 117 blows per minute, and falling by gravity alone; the effect of which, calculated as in the previous case, is equal to 709 lbs. or $6\frac{1}{4}$ cwts. falling 1 foot. The diagrams in Fig. 18 are taken below the piston, and those in Fig. 19 above the piston, when steam is used above, the hammer working with the same stroke of 10 inches at 150 blows per minute;

the effect of which is equal to 2396 lbs. or $21\frac{1}{2}$ cwts. falling 1 foot: showing a superiority of $3\frac{1}{4}$ to 1 over the hammer falling by gravity alone.

The diagrams in Fig. 20, Plate 66, are taken below the piston, the hammer working with a stroke of 5 inches at 147 blows per minute, and falling by gravity alone; the effect of which, calculated as before, is equal to 380 lbs. or $3\frac{1}{2}$ cwts. falling 1 foot. The diagrams in Fig. 21 are taken below the piston, and those in Fig. 22 above the piston, when steam is used above, the hammer working with the same stroke of 5 inches at 180 blows per minute; the effect of which is equal to 1149 lbs. or $10\frac{1}{4}$ cwts. falling 1 foot: showing an advantage of 3 to 1 over the hammer falling by gravity alone.

The Chairman observed there appeared to be two points particularly to be noticed in the hammer just described: the simple mode of altering the lap of the valve, by the use of a cylindrical valve that could be turned round by hand into any position between the two extremes of no lap or full lap; and the ingenious mode of attaching the piston rod to the hammer block for overcoming the difficulty experienced in previous hammers from breakage of the piston rod. He enquired how many of the hammers were now at work, and of what size, and what was the cost of the hammer.

Mr. Peacock replied that there were now three of the hammers at work, all of the size shown in the drawings, one of which had been working about eight months; the cost was about £175 exclusive of the anvil. He showed a full size specimen of the valve, and explained that it was worked by hand with the greatest ease, being made hollow for the steam to pass through, so that it was completely balanced; and having a lap half round the circumference at the top end, it could be turned round by hand so as entirely to prevent the steam entering above the piston, for giving light finishing blows with the hammer. The chief object in the hammer was simplicity of construction, by the absence of gearing for working the valve; it was

therefore not likely to get out of order, while the working was completely controlled by hand; and it was particularly serviceable for smith's work, where no two blows were wanted alike.

Mr. F. J. Bramwell had long been convinced that gravity alone was not sufficient for working steam hammers, because a great part of the effect was lost whenever the height of fall was diminished by having a large mass on the anvil. He had aided in devising a steam hammer some years ago for crushing ore and also for forging iron; the falling weight was 30 cwts., but by using steam on the top of the piston the force of blow of a large hammer was got out of a small one, with a rapidity of stroke that could not be attained by gravity alone. The piston rod was made very large, half the area of the piston, so that the steam had only the annular area to lift by; and for the down stroke the steam was exhausted from the bottom of the cylinder into the top, where it acted upon the whole area of the piston, producing a total effective pressure corresponding to half the area. Two of these hammers had been put to work at Rotherham about six years ago and continued working there satisfactorily. The principal difficulty he had experienced was in attaching the piston rod to the hammer block, which had been done in the first hammer with two keys driven in horizontally from each side, and with wood packing to produce a certain amount of elasticity; but the keys got loose with the jarring of the blows and came out. To prevent this they were then put in obliquely, inclined downwards, which caused them to remain secure; all elastic packing in the hammer block was abandoned, the keys being driven in tight to make a rigid attachment: and this plan succeeded entirely. The connexion of the piston also to the rod was frequently a difficulty, and he thought the best plan was to forge it solid on the rod, and make it steam-tight with Ramsbottom's packing rings, so as to have as light a packing ring as possible. Where a steam hammer was required he doubted whether it was ever desirable to work it without any steam on the top, but the valve now shown would be very useful for altering the degree of lap and varying the admission of steam above the piston. In the indicator diagram the vacuum shown above the piston in falling when the hammer worked single-acting seemed

much less than he would have expected, if there were no air drawn in except through leakages.

Mr. C. W. Siemens said it seemed extraordinary there should be so small a vacuum above the piston, when no air or steam was admitted; but this might be explained by the circumstance that the surfaces of the cylinder remained wet from the preceding up stroke, and a generation of steam would take place from them as soon as the pressure fell below that of the atmosphere.

Mr. C. Markham enquired how the length of stroke of the hammer was varied. There was a great advantage in being able to use steam above the piston when required, but he did not think it was desirable to do so always, as there would then be a loss in working with a short range, because a whole cylinder full of steam would be thrown away at each stroke.

Mr. Peacock replied that the length of stroke was varied entirely by the hand lever, which could be done to a great nicety after a little practice.

Mr. E. A. Cowper observed that the loss of steam in working the hammer at a short range with steam above the piston would be greatly reduced by the plan mentioned by Mr. Bramwell of enlarging the piston rod and using the same steam above the piston that had previously lifted the hammer; the additional work got out of the steam in the down stroke was then all gained. The indicator diagram taken from the top of the cylinder when the hammer was working single-acting showed the want of a steam jacket, by the fact of the pressure produced by generation of steam from the wet surface of the cylinder; and he believed all steam hammers required jackets quite as much as the cylinders of steam engines; for if there were any moisture on the surfaces of the cylinder it showed that a quantity of steam was passing through without doing duty, being merely condensed in the cylinder and then evaporated again. He enquired why the back pressure below the piston was so high in all the diagrams, and suggested that it might be greatly diminished by making the middle of the valve half a port longer than the distance between the ports, so as to obtain a much more free exhaust: this plan he had carried out extensively in steam engines with excellent effect.

Mr. Peacock replied that the greater part of the back pressure was due to the cushioning in the last portion of the stroke, as shown by the diagrams, and there was only a small back pressure in the previous portion of the stroke. Cushioning was necessary for lifting the hammer again more readily after the blow, and to ensure lifting it clear without a repetition of the blow. The addition of a steam jacket round the hammer cylinder would no doubt be desirable where economy of steam was of importance, though of course increasing the first cost to some extent; but at his own works the steam was not considered an important item, as it was supplied from vertical boilers heated by the furnaces, and there was still steam blowing off while the hammer was at work.

Mr. F. J. Bramwell asked whether the hammer had been worked by hand when the indicator diagrams were taken, as the length of stroke would then depend on the skill with which the handle was worked.

Mr. Peacock said the valve was worked by a boy according to the smith's directions, and the diagrams showed that practically the hammer could be worked by hand with great uniformity in the length of stroke.

He explained the mode of attaching the piston rod to the hammer block so as to make a good and durable connexion; the hammer block being made of wrought iron, with a bore hole carried right through, in order to get the boring bar in for boring the upper portion of the block. A hard wood packing of oak, teak, or ash was inserted in the bottom of the block between two wrought iron washers, against which the bottom of the piston rod bore with a cheese head, $\frac{1}{4}$ inch smaller in diameter than the hole in the block; above the cheese head was another washer, and then two cotters one on each side of the rod, which avoided weakening the rod by cutting cotter holes through it. The hammer was then put to work, and the cotters gradually tightened up; and after a week's work new cotters were put in slightly larger so as to fit tight, which would then last for three or four months without any attention.

Mr. R. Williams enquired what sort of gland was used at the bottom of the cylinder, and what packing was employed for the piston.

Mr. Peacock replied that it was simply an ordinary stuffing box at the bottom of the cylinder; the piston was made with two of Ramsbottom's packing rings, which would remain steam-tight for 18 months or more without taking out, and he had had a Nasmyth hammer working with them for four years. He was now making a 4 ton hammer on this construction, in which the exhaust side of the valve would be made longer than the distance between the ports, in order to prevent a vacuum being formed above the piston in falling when working single-acting, by allowing some of the exhaust steam from below the piston to pass into the top of the cylinder.

Mr. W. Naylor doubted whether the same accurate adjustment of the blow could be got in working the valve by hand as when gearing was used; in a rapid play of blows he thought the hammer would only just touch the anvil, without giving much force of blow, and the valve would have to be reversed some time before the piston reached the top of the cylinder, to prevent any chance of keeping the steam on too long. He had found the great desirability in a forge of having a hammer that could be worked single-acting or double-acting as required; for when the iron was brought under the hammer at a welding heat it wanted light quick blows at first for welding it together, and then heavy blows for working it into shape, which could be done with a double-acting hammer at the same heat; and the fewer heats the work had to go through, the better and quicker it was done. He thought the valve described appeared similar to that in his own hammer, which had been described at a former meeting. He asked whether any breakage of the cotters in the hammer block had occurred since first starting.

Mr. Peacock replied that they had never had any cotters broken during eight months' work, and the attachment of the piston rod and hammer block continued perfectly fast. The valve was designed as a simple form of balanced valve that could be cast all in one piece and required only turning up on the outside without any fitting. For ordinary smiths' work the hammer was oftener wanted without the steam on the top than with it; but in forging work under dies very heavy blows were required, and it was a great advantage then to have the means of increasing the force of blow with the same hammer. By dispensing with gearing for working the valve the construction was

much simplified, and the hammers were found to be handier for the men than a Nasmyth 15 cwt. hammer worked by gearing in the same shop: the boys who worked the valves got quite perfect in managing them after three or four days' practice, and gave exactly the force of blow that the smith directed.

Mr. J. Inshaw enquired whether there was any self-acting stop for preventing the hammer from striking the top of the cylinder, in case of the steam not being shut off in time.

Mr. Peacock said there was a roller fixed on the hammer block, which came against a trigger connected with the valve rod near the top of the stroke, and shut off the steam in time to prevent the hammer rising too high.

The Chairman proposed a vote of thanks to Mr. Peacock for his paper and the numerous indicator diagrams he had taken to illustrate the action of the hammer, which was passed.

The meeting then terminated.

BLAST – FURNACE WASTE GAS.

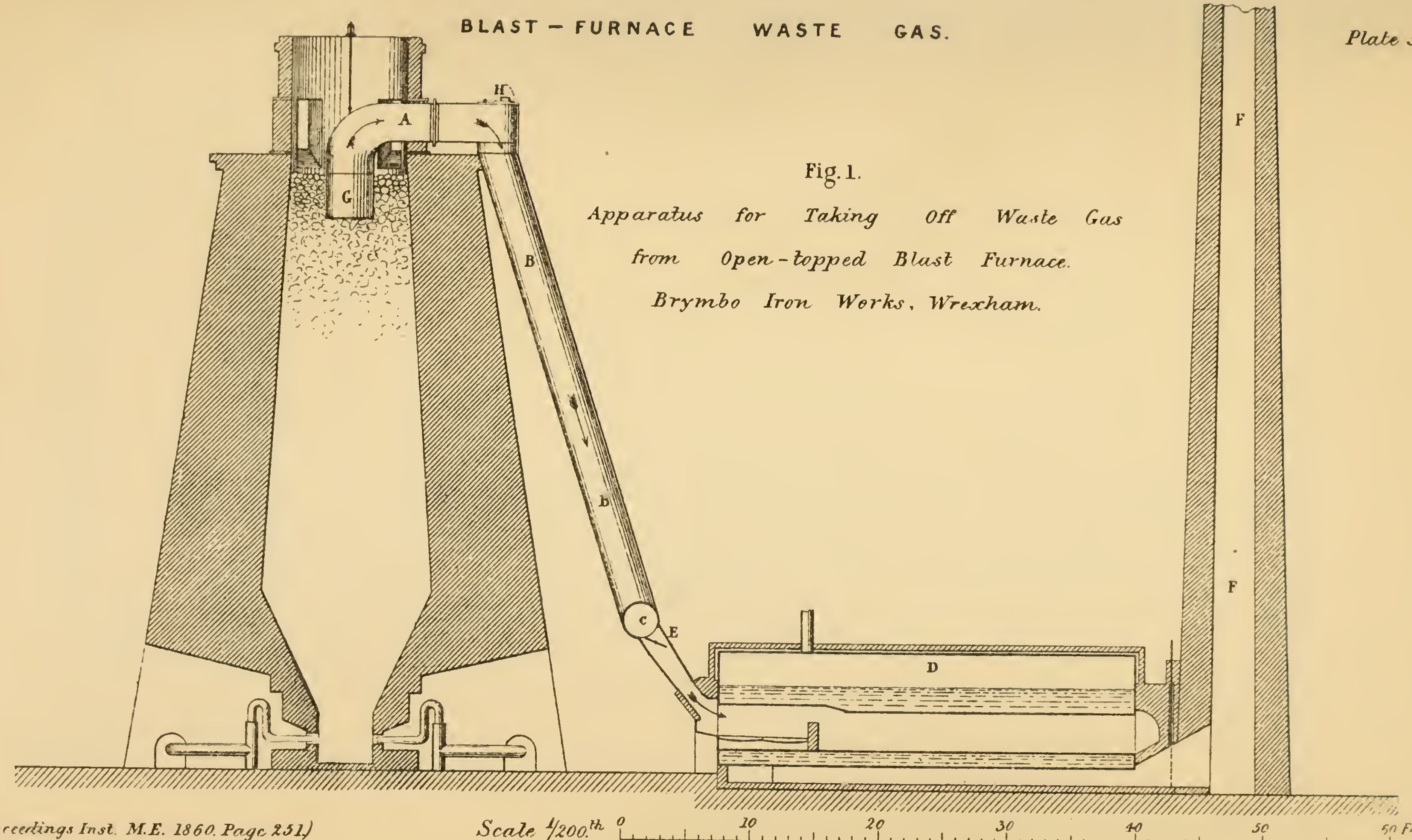


Fig. 1.

Apparatus for Taking Off Waste Gas from Open-topped Blast Furnace.

Brymbo Iron Works, Wrexham.

Scale 1/200th

BLAST - FURNACE WASTE GAS.

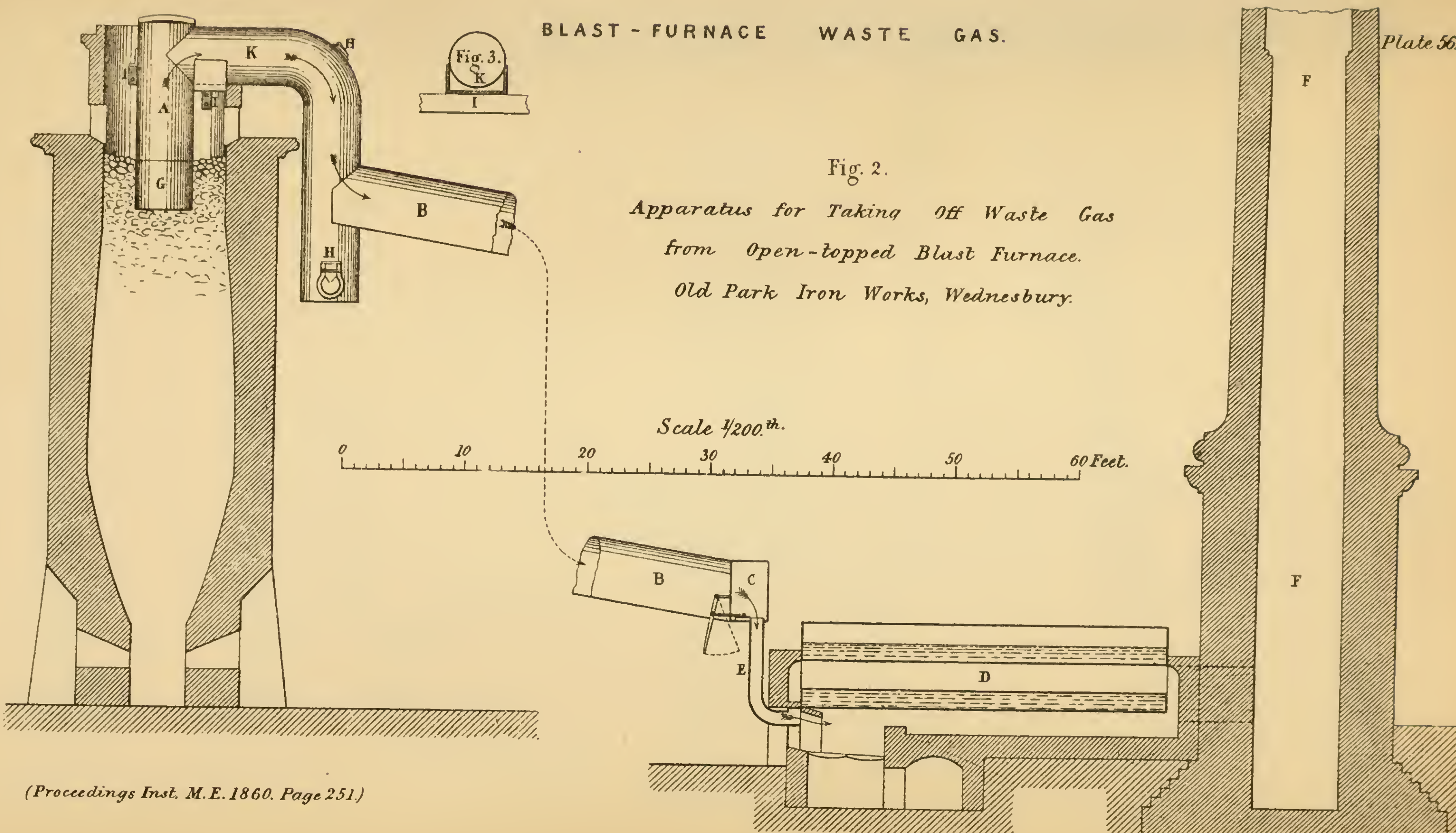


Fig. 2.

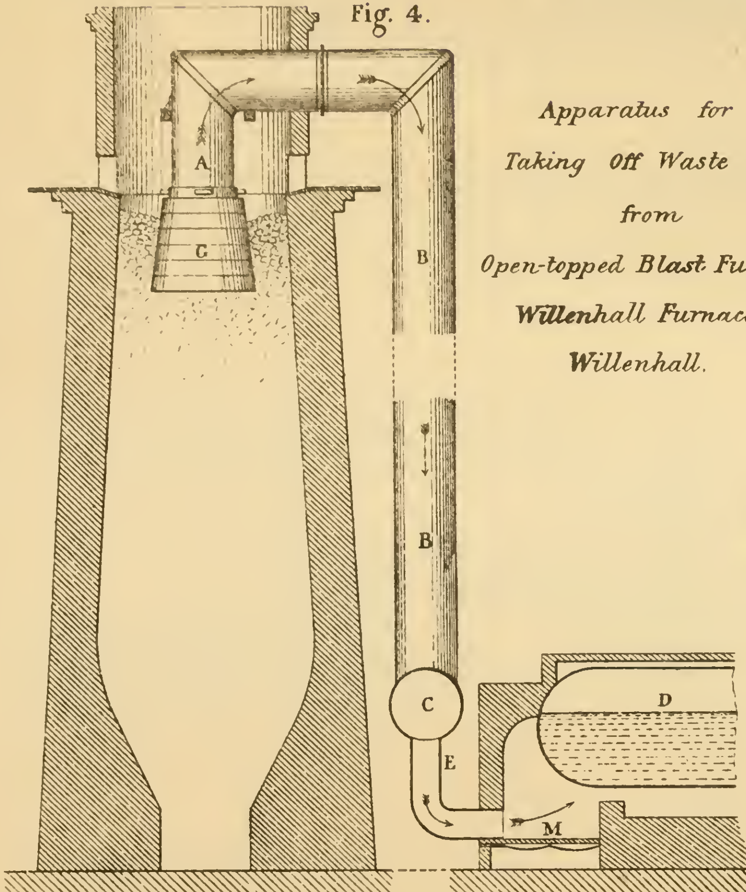
Apparatus for Taking Off Waste Gas from Open-topped Blast Furnace.

Old Park Iron Works, Wednesbury.

(Proceedings Inst. M.E. 1860. Page 251.)

BLAST-FURNACE WASTE GAS.

Fig. 4.

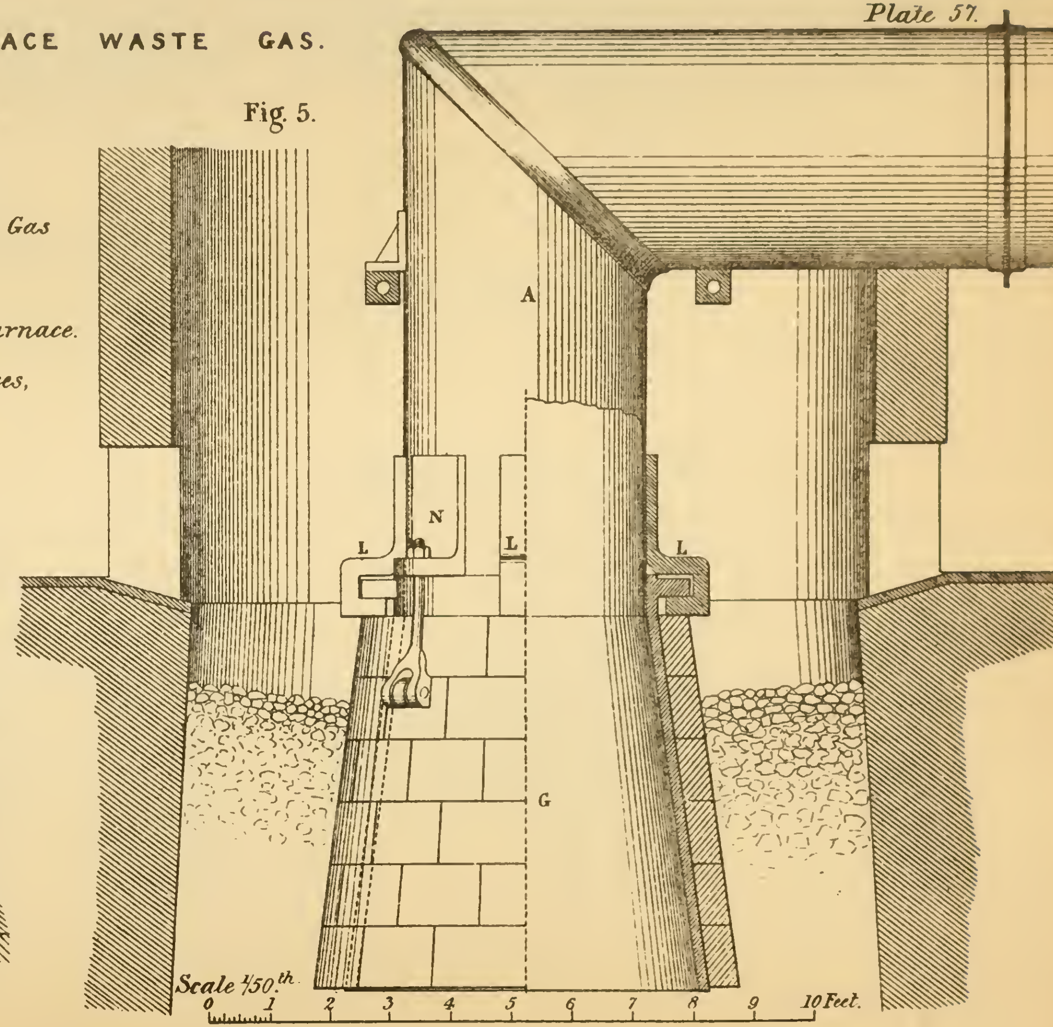


Scale 1/200th.

Apparatus for Taking Off Waste Gas from Open-topped Blast Furnace.

Willenhall Furnaces, Willenhall.

Fig. 5.



Scale 1/50th.

(Proceedings Inst. M.E. 1860. Page 251.)

Fig. 6. *Open Top of Furnace at Brymbo Iron Works, Wrexham*

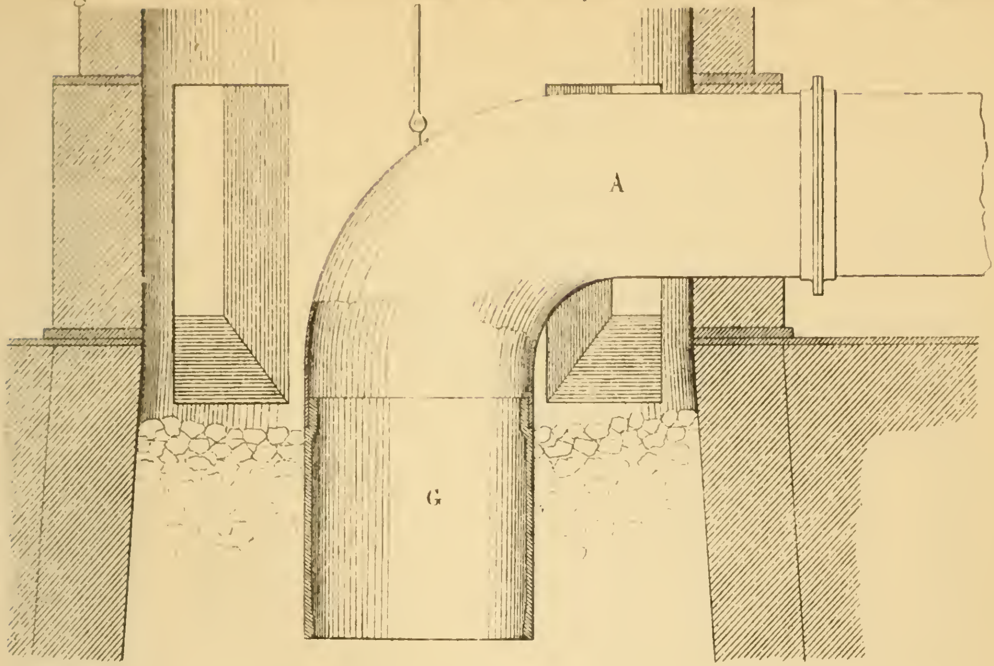


Fig. 7. *Open Top of Furnace at Old Park Iron Works, Wednesbury.*

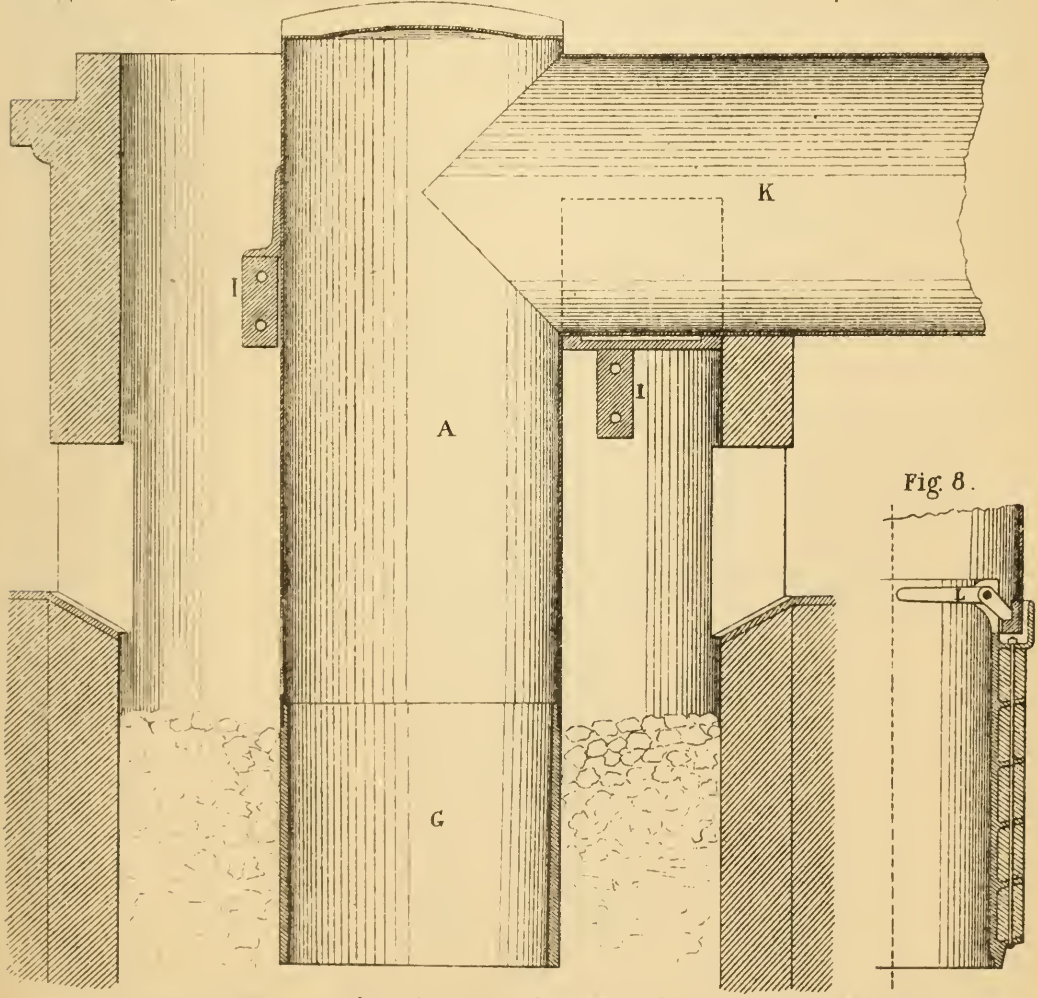


Fig. 8.

Scale 1/50th. 0 1 2 3 4 5 6 7 8 9 10 *Feet.*

Fig. 1. *Longitudinal Section.*

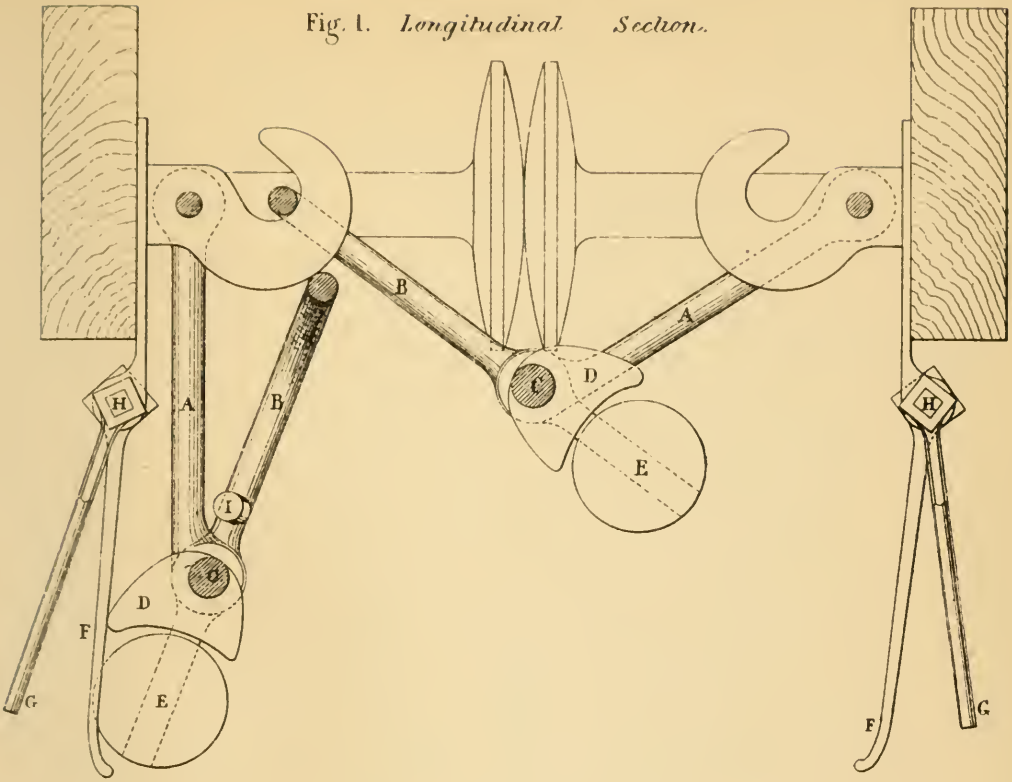
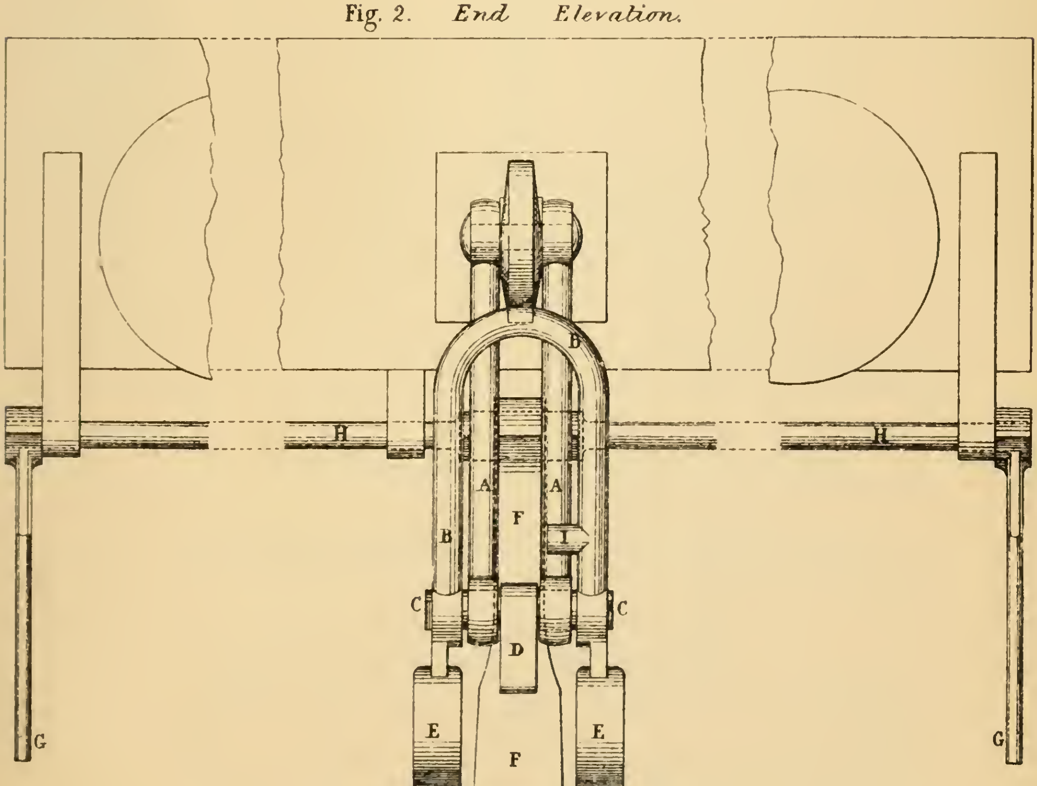


Fig. 2. *End Elevation.*



Scale 1/10th. 0 10 20 30 *Inches.*

Fig. 3. *Process of Coupling.*

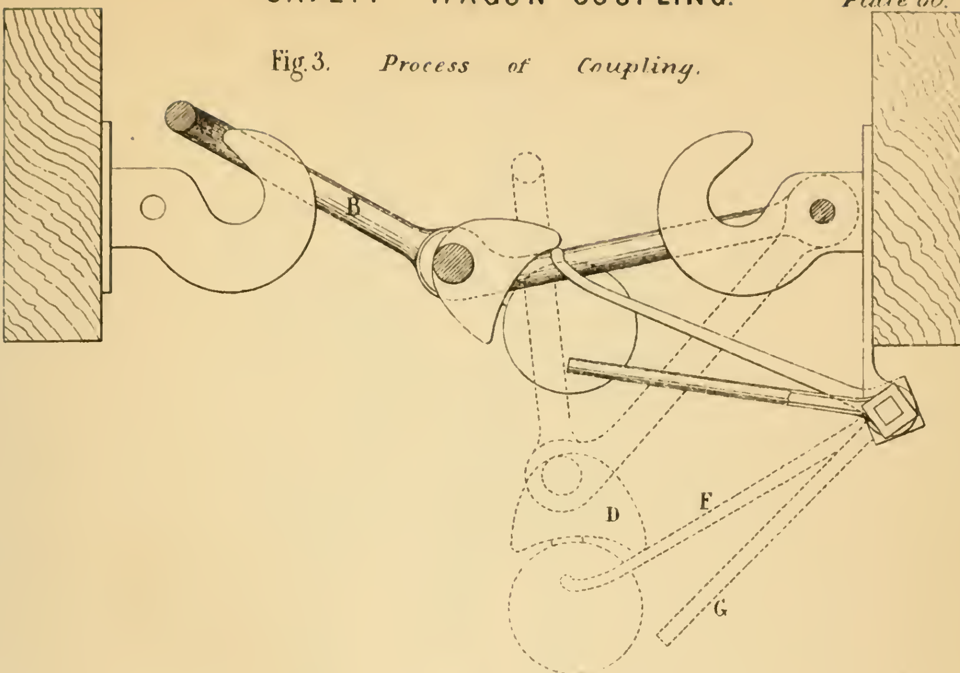


Fig. 4. *Process of Uncoupling.*

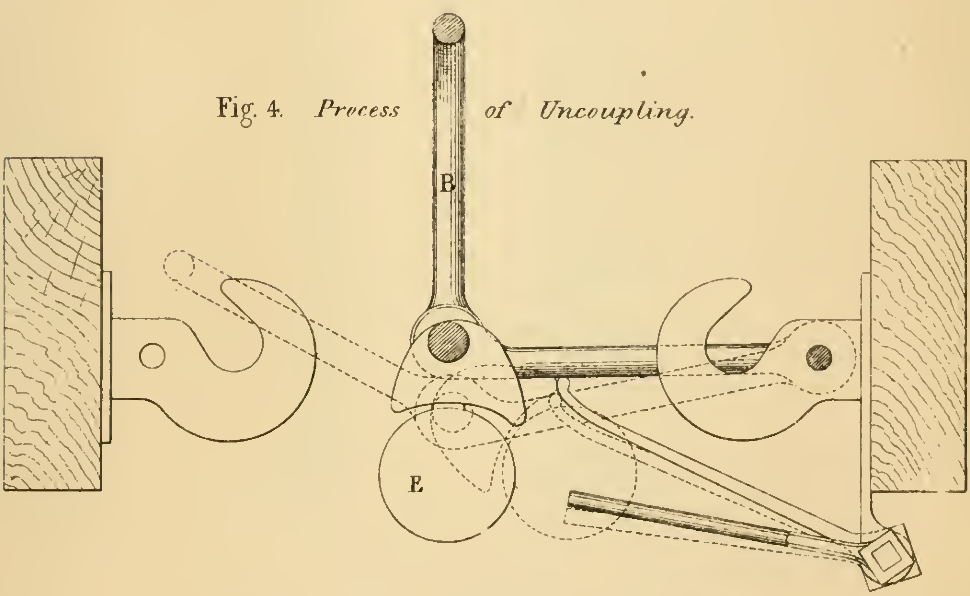


Fig. 5. *Side Elevation of Coupling.*

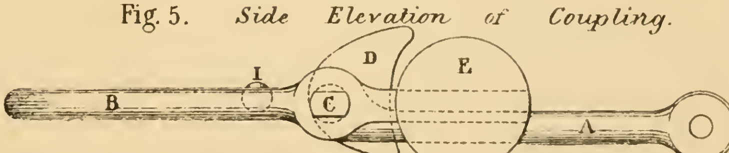
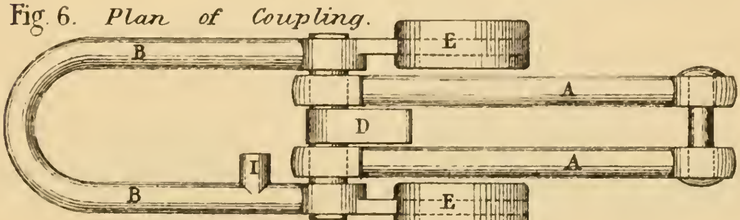


Fig. 6. *Plan of Coupling.*



Scale 1/10th. 0 10 20 30 *Inches.*

STEAM HAMMER

Fig 1. *Vertical Section*

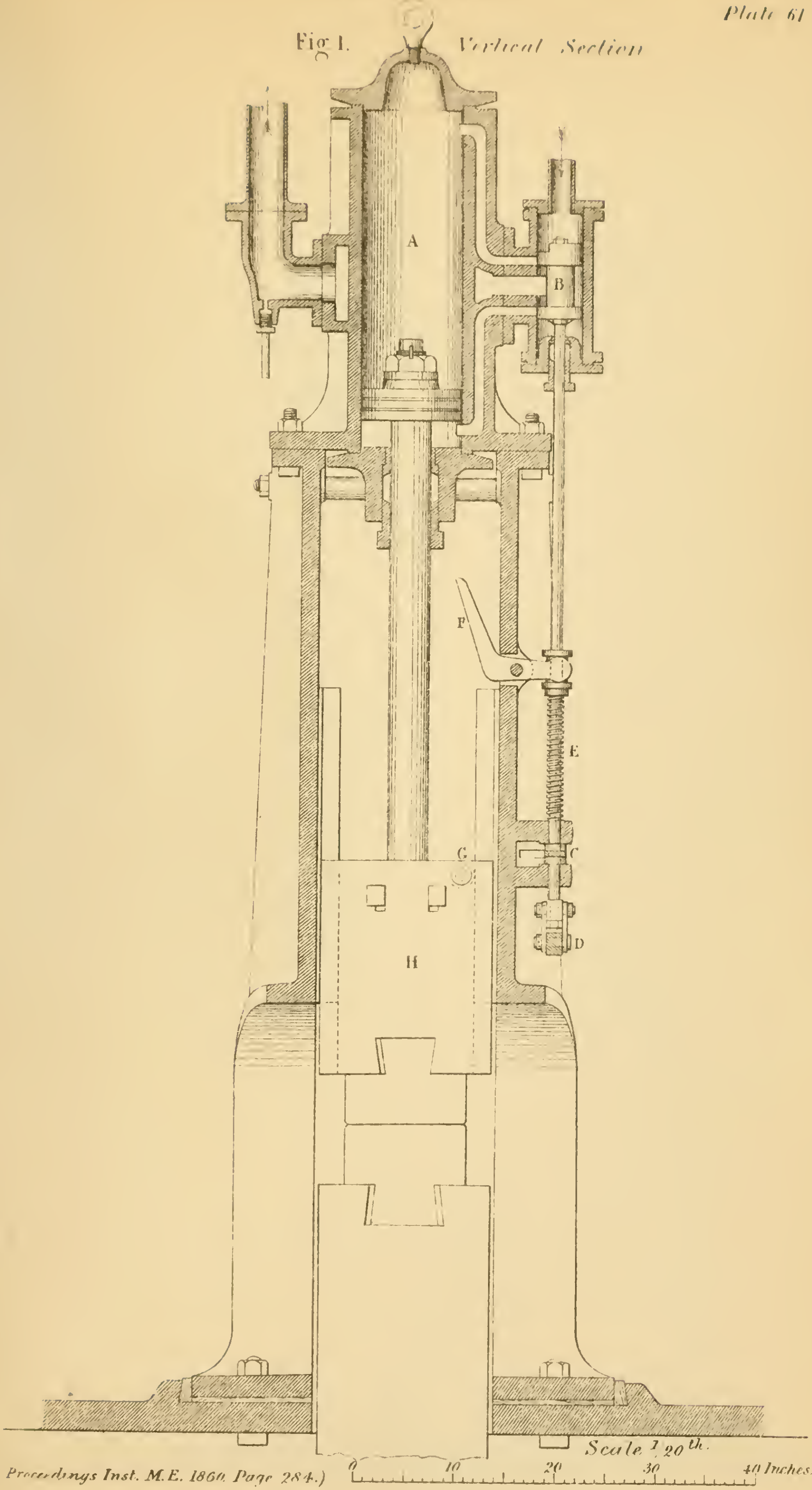


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Fig. 2.

Side Elevation.

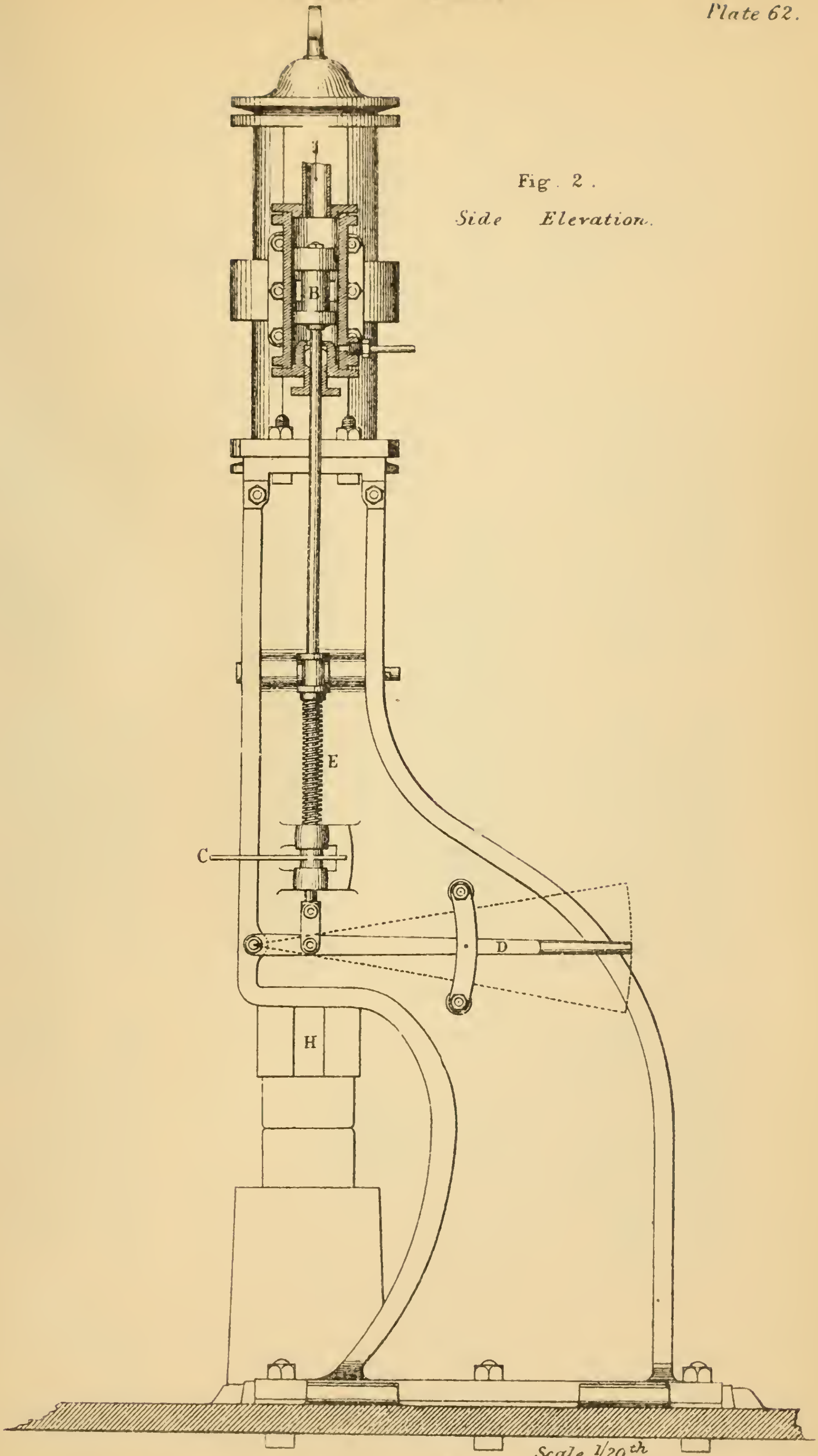


Fig. 3. *Sectional Plan through Cylinder and Valve Chest.*

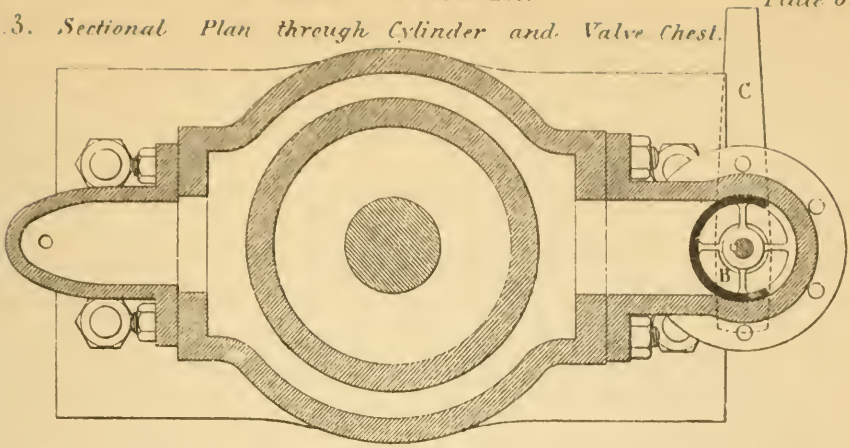
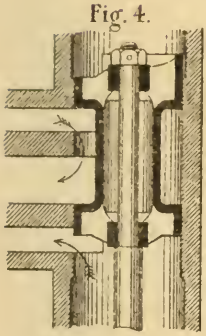


Fig. 4.



Vertical Section of Hammer Block.

Fig. 11.

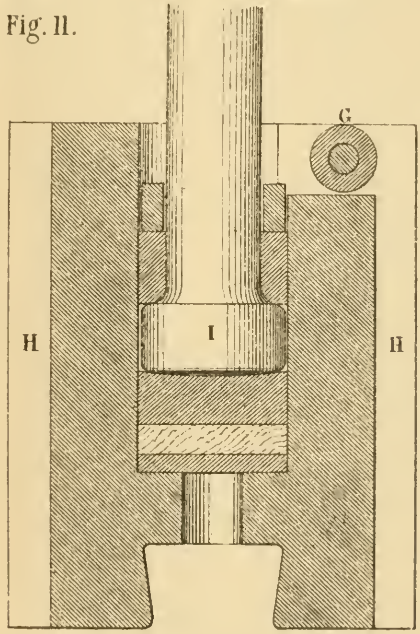


Fig. 8.

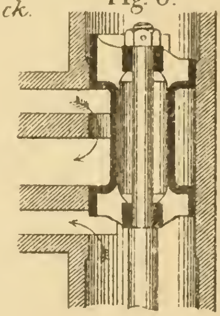


Fig. 5.

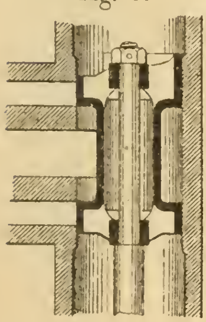


Fig. 9.

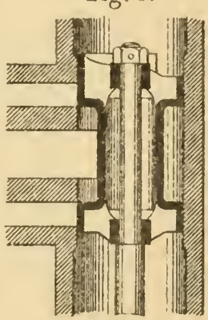


Fig. 6.

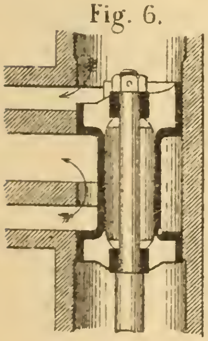


Fig. 12. *Plan of Hammer Block.*

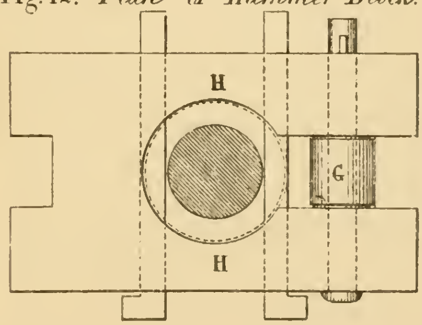


Fig. 10.

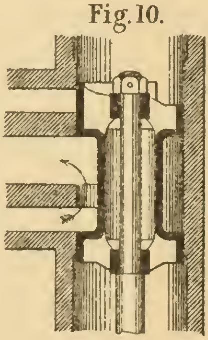
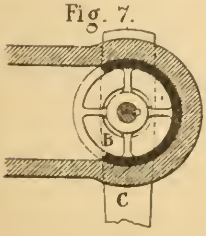
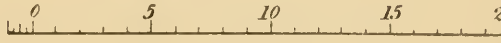


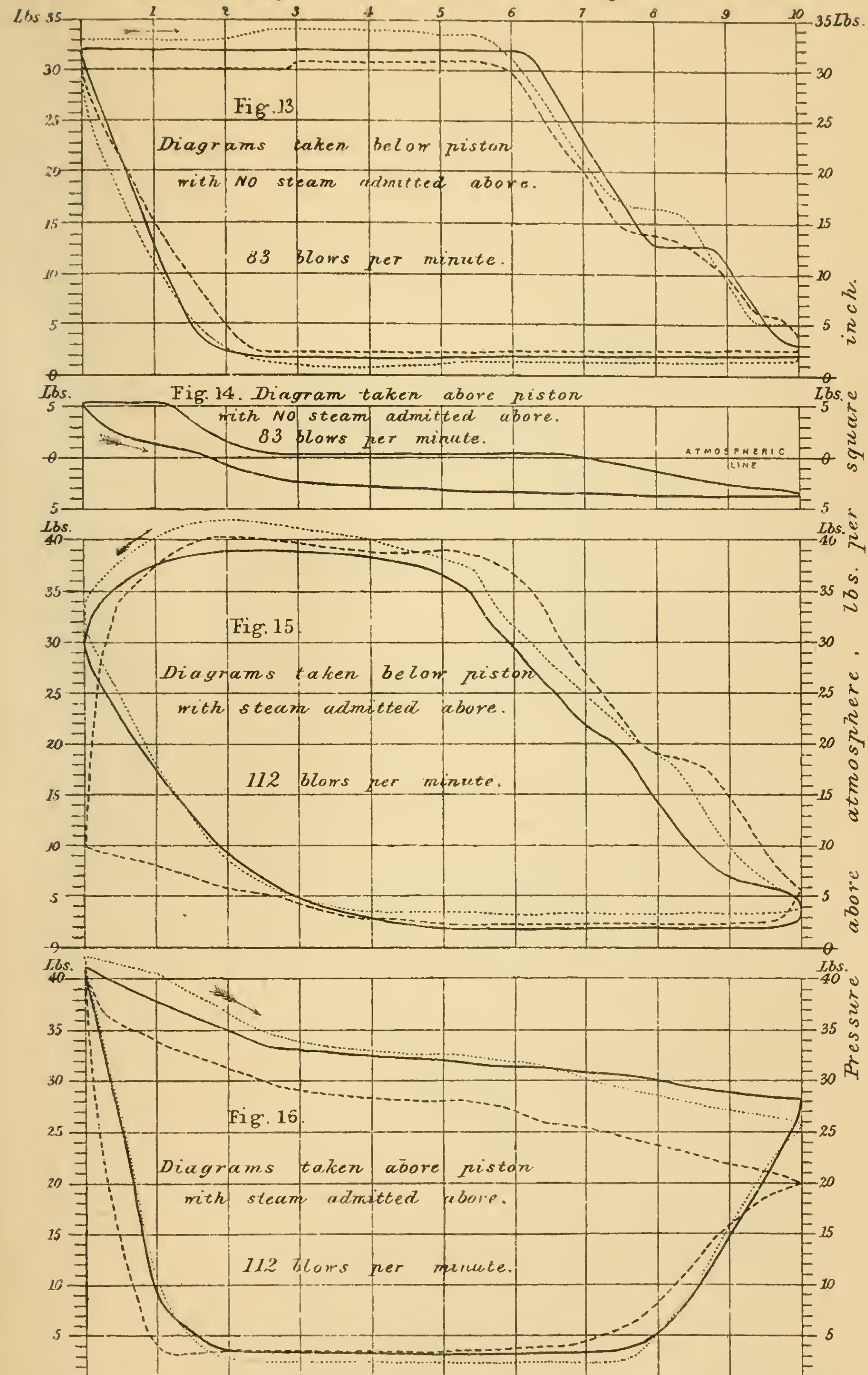
Fig. 7.



Scale 1/10th.



Indicator Diagrams with 20 inches length of stroke.



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Indicator Diagrams with 10 inches length of stroke.

Fig. 17. *Diagrams taken below piston, with NO steam admitted above.*

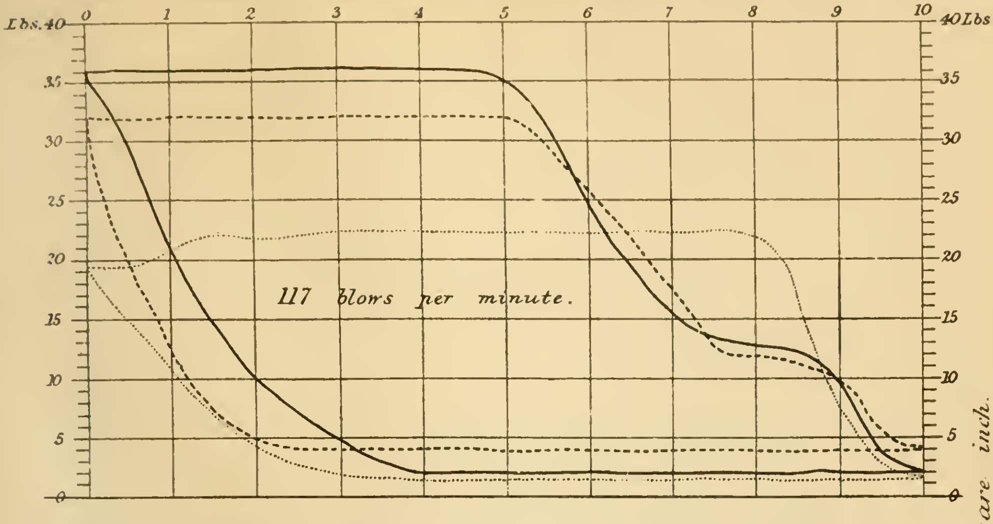


Fig. 18. *Diagrams taken below piston, with steam admitted above.*

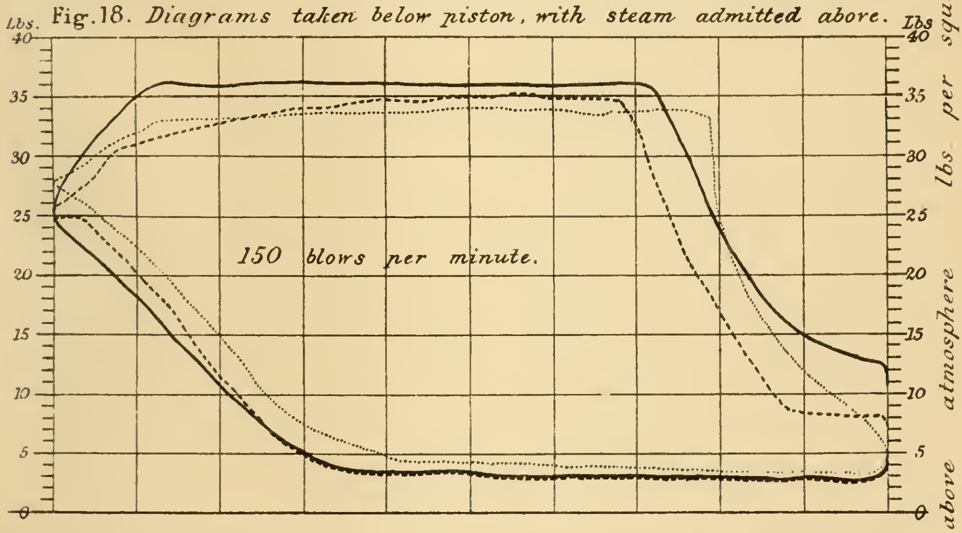
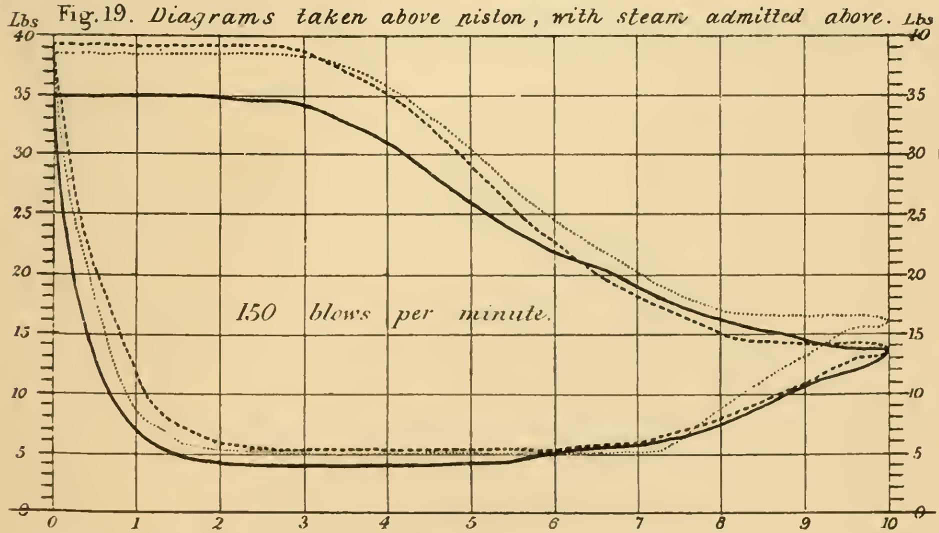


Fig. 19. *Diagrams taken above piston, with steam admitted above.*



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Indicator Diagrams with 5 inches length of stroke.

Fig. 20. *Diagrams taken below piston, with NO steam admitted above.*

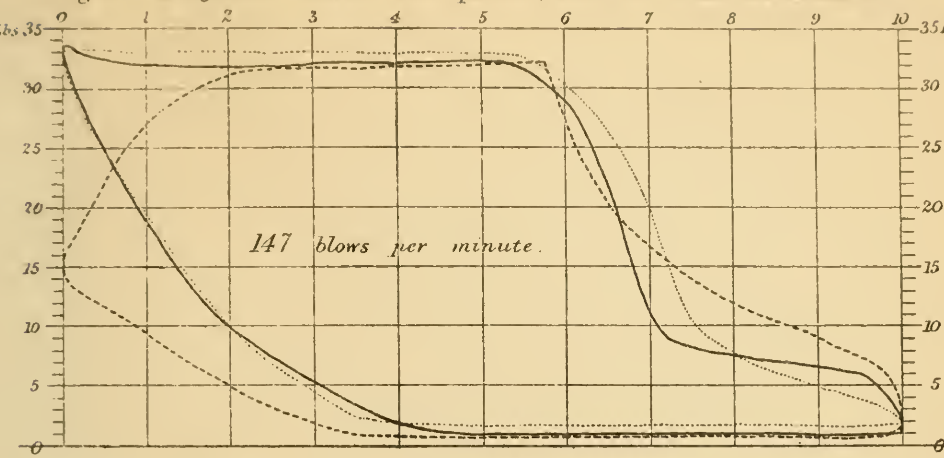


Fig. 21. *Diagrams taken below piston, with steam admitted above.*

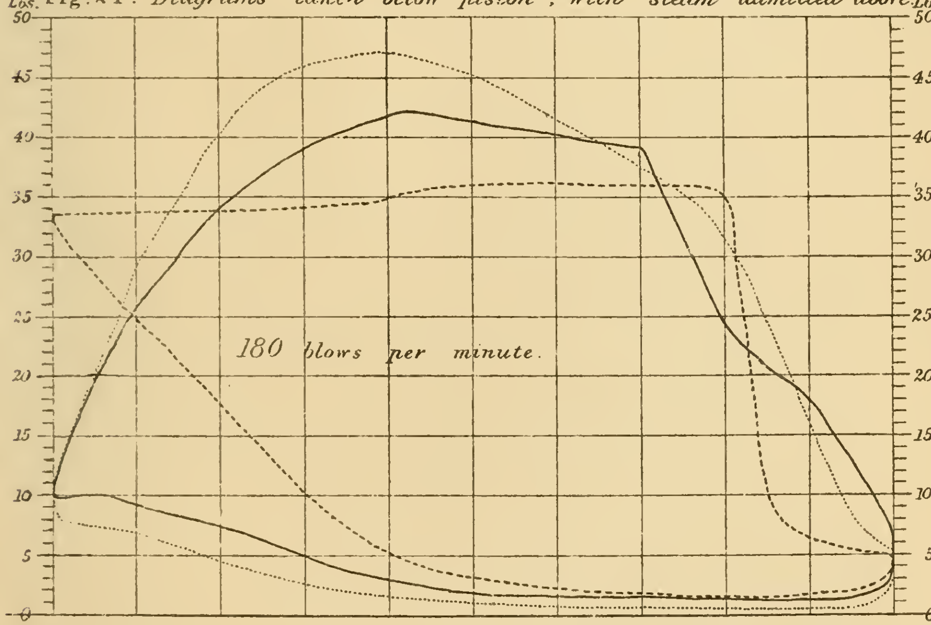
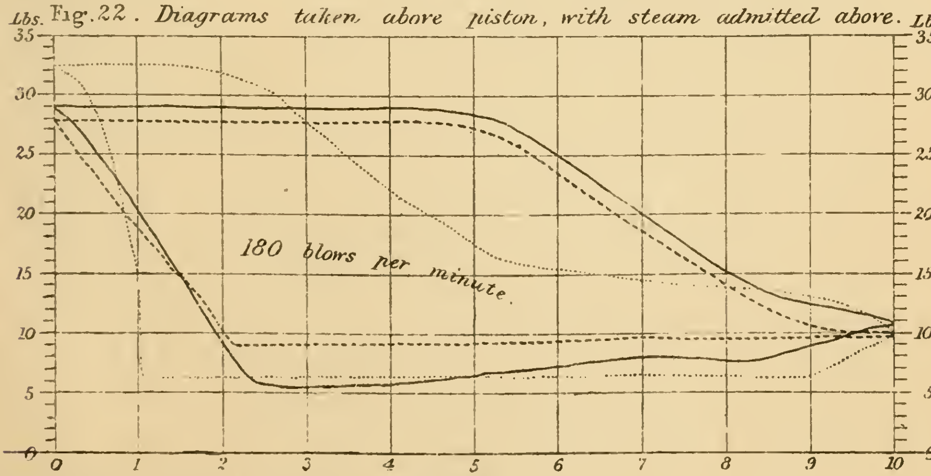


Fig. 22. *Diagrams taken above piston, with steam admitted above.*



Pressure above atmosphere, lbs. per square inch.

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